ALLIS-CHALMERS

ELECTRICAL REVIEW

March • 1944

Inverters for changing d-c to a-c on shipboard are mass-produced, assembled, and tested largely with the sensitive, skilled hands of women. This 1.25 kva size unit, with a-c and d-c rotors on a common shaft, is totally-enclosed and spray-proof.

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ALLIS-CHALMERS

ELECTRICAL REVIEW

C O N T E N T S

"BIG INCH" OIL — UNDER CONTROL

Via pipe lines, Texas oil fields have literally been transplanted to the oil-hungry East. This is the story of the power and the control for the "Big Inch" and the "Little Inch" that all America has watched to completion.

A. S. Munneke and Jack L. Gates
ELECTRICAL ENGINEERS • WAR EMERGENCY PIPELINES, INC.

● Before the war most of the petroleum and its products consumed in the Eastern states were carried from the Gulf coast of Texas to the refineries on the Eastern seaboard by tankers. When the war caused most of these tankers to be diverted to overseas duty, it became necessary to make up for this loss in transportation facilities, resulting in the planning and authorizing of the 24-in. crude oil pipe line and the 20-in. products pipe line.

THE "BIG INCH"

The 24-in. crude oil line, extending 1,253 miles from Longview, Texas, to Phoenixville, Pennsylvania, has now been in complete operation since October, 1943. A network of feeder lines at the Texas end and distribution lines from the Eastern terminals to various refineries increase the total length to 1,464 miles. To fill this tremendous length of pipe, 3,782,000 barrels of oil are required.

More than 300,000 barrels of oil per day are being sent over this line, so that enough power must be supplied to move a continuous 1,464-mile column of oil from Longview, Texas, to Phoenixville and the Eastern terminals at a velocity of 6.7 feet per second. It was decided to use a pipe 24 inches in diameter, designed for 770 psi discharge pressure and about 50 psi positive suction pressure at each station. Each station was to have the same discharge and suction pressure so that the station equipment could be duplicated, thus making the units interchangeable, reducing manufacturing costs and speeding delivery.

The 720 psi pressure at each station is developed by three centrifugal pumps in series. Each pump has a 16-in. suction and a 12-in. discharge nozzle and at 1,780 rpm is rated 8,750 gallons per minute at 630 ft. head when pumping crude oil having a specific gravity of 0.84. Each pump is driven by a 1,500 hp, 3-phase, 2,300-volt squirrel cage induction motor.

AT LEFT: Every 52 miles or so from Longview, Texas, to Phoenixville, Pennsylvania, a combination of three of these centrifugal pumps is required to keep a continuous column of crude oil 1,464 miles long moving through the "Big Inch" pipe. They are now depositing a desperately needed 300,000 barrels of oil in the East every day.

With this pumping arrangement and a pressure drop in the line of 13.7 psi per mile, the desired spacing between stations was determined to be about 52 miles, although the actual distance between stations varies because of differences in elevation. This distance is such that the pressure developed at any given station is equal to the difference in the static head between that station and the next succeeding station, plus the pressure drop caused by friction at capacity flow between the two stations.

An emergency schedule, the critical materials involved, and cost of installation of the line all affected the selection of station equipment and spacing between stations, of course.

Power sources

The suction pressures are fixed at about 50 psi, which more or less locates the stations. This means that the stations cannot be located where power is available, but rather the power facilities must be extended to the station sites.

The power for these stations is supplied by 16 power companies, and transmission lines varying in length from a few hundred feet to 58 miles were constructed from existing lines to the station sites. The primary voltage of these lines varies from 22 kv to 110 kv, but in all cases the secondary voltage at the station is 2,400 volts.

In general, the electrical substation has one 3,750 kva, three-phase, oil-immersed, self-cooled transformer with a secondary voltage of 2,400, and it is equipped for future forced cooling which would increase the rating to 5,000 kva. The transformer is protected on the primary side by a set of disconnecting fuses and an air break isolating switch.

A bank of three single-phase, 2,400 — 240/120-volt transformers is mounted on a small secondary structure just outside of the main pumping station. This bank has one 25 kva, and two 15 kva transformers for single-phase lighting and three-phase auxiliary power. The main power feeders run from the secondary terminals of the main transformer to this secondary structure, at which point a three-phase gang-

operated disconnect switch can isolate the motor control circuits in the station itself.

From this disconnecting switch the power feeders go into the motor room through porcelain wall entrance bushings, and they terminate on bushings located on top of the main metal-clad switchgear. The motors and switchgear are in the same room, but are separated from the pump room by a firewall.

Switchgear simple

This metal-clad switchgear is of the lift type, and both full and reduced voltage starting are used. The motors have a pull-out torque of about twice full load torque, and can therefore carry the pumps at full load through a voltage dip as low as 70 percent of normal. This means that the choice between reduced and full voltage starting is determined by the ability of the power company to handle this starting demand, and still maintain satisfactory voltage in its system.

In each station, the switchgear consists of an incoming line unit, an auxiliary unit and a starting unit for each motor. The incoming line and motor starter units are equipped with electrically-operated, capacitor-tripped oil circuit breakers, each having an interrupting capacity of 100,000 kva. This switchgear is essentially standard metal-clad equipment with undervoltage, over-current and reverse phase relays, and other standard accessories. In addition to the usual protection against undervoltage, motor and station overcurrent and short circuits, pressure switches are provided on the suction and discharge lines to function at abnormally high or low pressure.

If the station suction pressure drops to 35 psi, an audible alarm is sounded. If this pressure continues to fall to 15 psi, the suction pressure switch operates to shut down the high pressure unit instantaneously, and the other two units follow at approximately two-second intervals. However, if the suction pressure should recover, the relays are de-energized and further tripping is arrested, but any units which have been taken off the line must be restarted manually.

If the station discharge pressure exceeds 800 psi, the discharge pressure switch functions and units are shut down in the same manner as on low station suction pressure. If the abnormally high pressure should be reduced during this time-interval of sequential tripping, all further action is arrested, but any units which have been disconnected must be restarted manually. No units may be restarted as long as the abnormal condition persists.

Starting the pumps

The pumping units can be started from either of two points. One is at the switchgear itself, and the other is at an explosion-proof push button mounted near the pump in the pump room.

The motors are rated 1,500 hp, 1,800 rpm, 40 C rise, 2,300 volts, 3-phase, 60 cycle. The mounting dimensions, shaft diameter, and length of shaft extension of the motors are standardized, so that these motors will be interchangeable regardless of manufacture. The special shaft extension goes through the firewall and firewall stuffing box. This permits removal of the pump or its rotating element for repair by disconnecting the coupling, without disturbing the motor.

The exhaust air discharged from the top of the motors is carried through a system of duct work by exhaust fans. This warm air is either passed through flame arrestors into the pump room for heating or discharged through the roof, depending on weather conditions.

The pumps are started with the suction valve open and discharge valve closed to minimize the accelerating torque required. After the unit has reached full speed, the discharge valve is opened and the pump picks up load.

PRODUCTS LINE

The 20-in. products line begins at Baytown, Texas, and extends to the New York area, a total of 1,475 miles. The rated capacity of the line is 235,000 barrels per day. This line joins the 24-in. crude line at Little Rock, Arkansas, and from there to the Eastern terminal, the pipes are laid on the same right-of-way, and the 20-in. pipeline pumping stations are on the same sites as the stations for the 24-in. crude line. Thus, considerable savings were possible in investments for right-of-way station sites; and in power and operating costs.

There are 30 pumping stations on this products line, spaced approximately 52 miles apart, and the total electric motor capacity is about 113,500 hp. In general, each station has three centrifugal pumps operating in series, each unit being driven by a 1,250 hp induction motor. The substations have the same type of construction as those used on the 24-in. line and, of course, the same variety of primary voltages. In all cases, the power is supplied to the motor control at 2,400 volts.

Metal-clad switchgear is used in all stations for the control of the main motors. The switchgear is of the lift type and has an incoming line unit, auxiliary unit, and a starting unit for each motor. All breakers have 100,000 kva interrupting capacity and are electrically operated. This switchgear is located in the control room at the discharge end of the station building, separated from the pump and motor rooms by firewalls. The control room has a slight pressure maintained at all times by a blower mounted above the control room ceiling. The blower delivers a small quantity of clean air from the outside into the control room so that no accumulation of gaseous vapors is possible and standard switchgear and associated equipment can be used. The station control systems for the products line are more elaborate than on the crude oil line, so that reduced operating expense, more uniform delivery of full capacity and better separation of the various petroleum products can be expected.

Control desk

The station operation is controlled from a desk mounted against the firewall between the control room and pump and motor room. On this desk top is a schematic diagram showing the pumps, motors, piping, and all valves pertaining directly to station operation. Arrows are placed along this piping diagram to show the direction of flow of the fluid through the station. Small indicating lights are located at appropriate points on the motor, pump, and valve diagrams to indicate the position of the valves and if

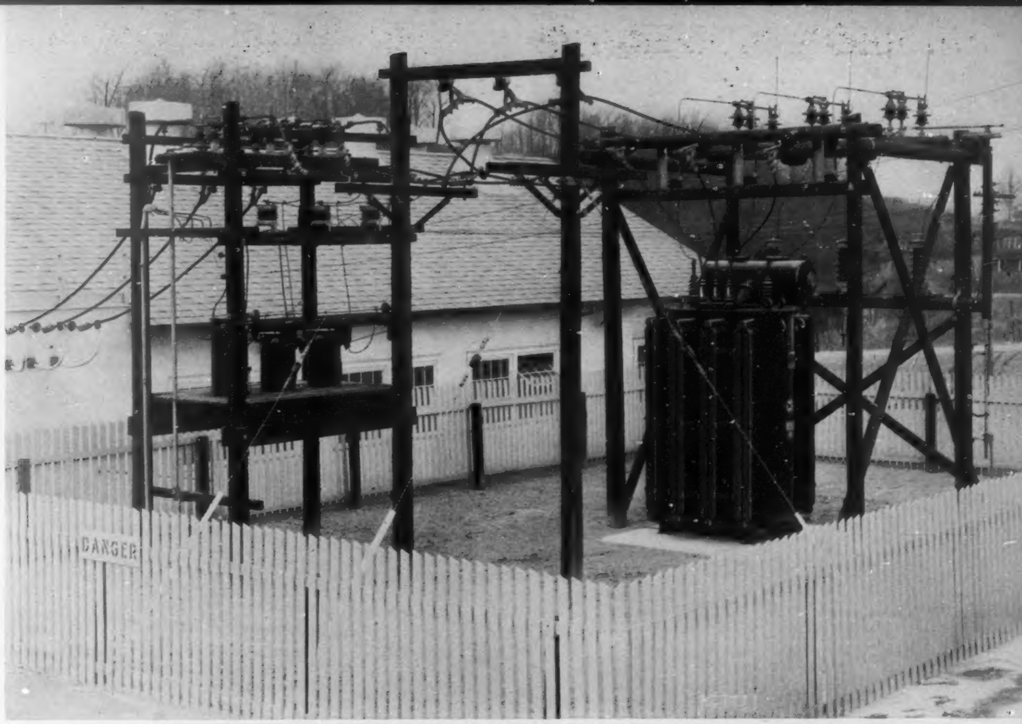


Fig. 1 — Each electrical substation on the "Big Inch" has one 3,750 kva, three-phase, oil-immersed, self-cooled transformer, with a secondary voltage of 2,400. A set of disconnecting fuses and an air break isolating switch protect the transformer on the primary side.

bearings and pump casings are at safe operating temperatures.

A gauge board mounted above this desk contains the pressure controls, pressure gauges, flow meter, air regulating valve, and a clock. It has a metal housing which extends through the firewall into the pump room, with the front portion completely vapor-tight and sealed against the firewall partition by gaskets. All piping to the gauge board enters from the pump room side and is accessible from the pump room side only.

The firewall has a glassed section two feet high extending several feet on each side of the gauge board. This gives the operator a clear view of the pump and motor room right from his desk.

As in the crude oil line, there are three pumps in series, but each is driven by a 1,250 hp, 2,400-volt, 3-phase, 3,600 rpm induction motor. Each motor has an extended shaft which passes through the firewall stuffing box into the pump room where it is coupled to the centrifugal pump. The motors were supplied by several manufacturers, but the mounting dimensions were standardized to insure interchangeability.

These motors discharge the warm air through the top. Similar to the crude line stations, a duct with a hood attached draws the heated air from the motor by means of a small exhaust fan mounted in the duct itself. In the summer this exhaust is ejected through roof ventilators, but during cold weather this warm air is discharged through flame arrestors into the pump room.

Temperature protection

The motors have temperature detectors on both bearings and in the windings. If the bearing temperature rises above a safe value, this temperature device automatically trips the individual motor circuit breaker, sounds an alarm and illuminates the proper indicating light on the control desk. Should the motor winding temperature become too high, the protective device sounds an alarm and again an indicating light goes on. It was considered advisable not to have this device drop the unit off the line because in most cases the operator can bring the temperature down by reducing the load or by some other means, and thus avoid unnecessary shutdown.

Temperature detectors are attached to the inboard and outboard bearings and case of each pump, where they operate in exactly the same way as the temperature protective devices on the motor bearings.

In addition to the unit temperature protective instruments, each station has several pressure switches which protect the station as a whole rather than any particular unit. These consist of low suction pressure, high pump case pressure, high discharge pressure, and low air pressure relays.

The low station suction pressure device is arranged to lock out the incoming line circuit breaker until there is enough suction pressure from the station below to allow safe starting of the centrifugal pumps. If one or all of the pumps are in operation and the suction pressure falls below as a safe value, the instrument closes the trip coil circuit of the incoming line breaker, sounds an alarm, and lights the proper indicating lamp on the control desk. Similarly, the high discharge pressure device takes the station off the line immediately in case of excess pressure in the discharge line.

Excess pressure sequence

The high pump pressure device actually ties in on each pump unit, although there is only one in a station. In addition to sounding an alarm and lighting on indicating lamp, it starts this sequence:

If the three pumps are running in series (which is normal operation), and for some reason the pressure increases above a predetermined value on the dis-

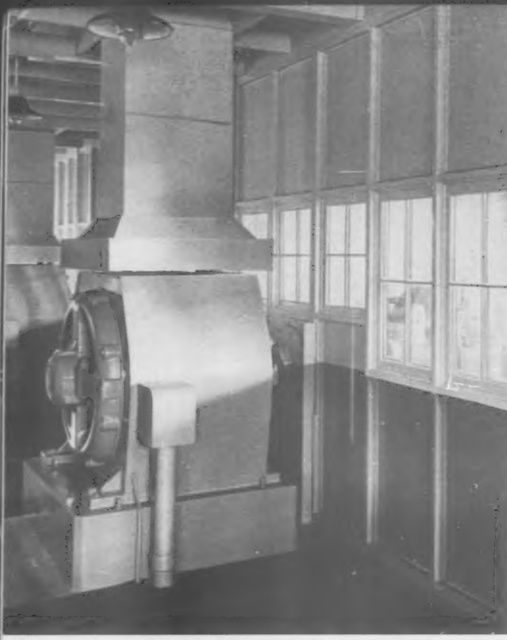


Fig. 2 — Motors and switchgear for the "Big Inch" are separated from the pump room by a firewall. The 1,500 hp, 1,800 rpm motors have standardized mounting dimensions, shaft diameters and shaft extension lengths, being interchangeable regardless of manufacture.

Fig. 3 — Special motor shaft extensions go through the firewall and firewall stuffing boxes, permitting removal of the pump or its rotating element for repair by disconnecting the coupling, without disturbing the motor. The series of three pumps develops 720 psi pressure.

charge of No. 3 unit, that unit is immediately taken off the line. When this happens, a relay is actuated in the trip circuit of No. 2 unit, which in two to three seconds, depending on operating conditions, drops the unit from the line. After No. 2 unit trips, the same procedure follows for No. 1. If at any time during this sequence the pressure decreases to a safe value, these relays are taken out of the circuit and go back to normal operation. However, the operator must restart manually any unit that has been taken off the line by abnormal pressure.

A pneumatic regulating valve is in the discharge line of each station. This valve maintains the line pressure at a value set on the pressure control at the control desk. As proper operation of this regulating valve depends on a supply of air from the station air compressor, a pressure switch is installed for sounding an alarm and lighting an indicating lamp if this pressure fails.

Suction and discharge valves on these pumps are motor-operated, and limit switches are tied in with the control scheme to give several unique safety features.

How the station starts

Perhaps a better understanding of the functions of these various devices can be had by going through the steps of an actual start. Suppose the operator has been ordered to put his station on the line, and he has already made necessary valve settings and the station has the required suction pressure. He then walks to the control desk and presses the "start" button, which has no other function than closing the contactor on the suction valve. The suction valve opens and, during its travel, both a green and an amber light appear on its symbol on the schematic diagram (both lamps lighted indicate that the valve is operating). When the valve reaches the full open position, the green light is extinguished, leaving only the amber light. Now limit switches on the valve close to actuate the control circuit of the circuit breaker in the switchgear. In the case of reduced voltage starting this circuit closes the starting breaker.

When the motor approaches full speed and the running breaker closes, a circuit to the discharge valve is set up and this valve starts opening. Thus, no load is put on the motor until it has reached full speed. The discharge valve then continues to open and, as in the case of the suction valve, both the green and amber lamps are lighted. When this valve reaches its full open position, the green light is extinguished and the pumping unit is on the line. The limit switches on both valves are so arranged that if for any reason (defective wiring or otherwise) the suction valve should leave its open position, the circuit breaker for the unit is immediately tripped. This eliminates the possibility of the pump running without adequate suction pressure.

This same procedure is followed in putting No. 2 and No. 3 units on the line. In other words, the operator pushes one button and from there on the sequence control scheme takes charge and the unit is automatically put into operation. If at any time after the starting sequence has been initiated, it is desired to shut the unit down, the operator merely pushes the "stop" button. As a result, the motor circuit breaker is tripped, the valves automatically close, and all devices reset to be ready for a new start.

When trouble comes

We will now assume that all three units are operating normally and see what would happen if trouble developed. Suppose that the outboard bearing of No. 1 pump should become overheated. The temperature detector closes three contacts, one lights a red indicating lamp located in the outboard bearing symbol on the control desk top, the second contact trips the circuit breaker, and the third contact sounds the station alarm. Continuous sounding of the alarm is un-

desirable, so an alarm cutout button is installed on the control desk. However, this does not prevent the alarm operating should trouble occur at any other point; nor is it necessary for the operator to reset the alarm for the existing trouble spot, as the alarm will automatically reset when the trouble is cleared.

However, it is impossible for the operator to extinguish the indicating light; this can be done only when the temperature detector is reset by hand. As a further precaution, these instruments are so arranged that they cannot be reset until the trouble is cleared. The protective instruments are usually located near the possible source of trouble, and since the unit cannot be started until this device is reset manually, the operator will be induced to make a closer inspection of the trouble than he would if the whole difficulty could be handled from the control room. All of the protective devices operate in a similar manner, except that sometimes auxiliary relays are required. Generally, the amount of auxiliary equipment is kept at a minimum, and, if at all possible, the protective devices operate direct.

The station as a whole is protected against high discharge pressure, low station suction pressure, high line discharge pressure, and incoming power overcurrent. In each case, the relay will trip the main incoming line breaker, sound an alarm, and illuminate an indicating lamp.

Each motor is protected against high bearing temperature, motor overcurrent, and high winding temperature. With the exception of motor winding temperature relay, all of these devices trip the breaker of the individual unit, sound an alarm, and light an indicating lamp. Each pump is protected against high bearing and casing temperature. When any of these pump relays operate, the unit is taken off the line, an alarm is sounded, and indicating lamp is illuminated and both suction and discharge valves return to the closed position. In addition, the station is protected against low air pressure and high sump level, either of which conditions will sound an alarm and light an indicating lamp on the control desk.

Stopping the units

Normal stopping of a unit can be done from any of three points — the "stop" button on the control desk, the control switch on the switchgear, or a "run-stop" push button located near the pump in the pump room. However, these units may be started only from the control desk. The push button in the pump room and the control switch on the switchgear must be in the "run" position before a unit can be started. This

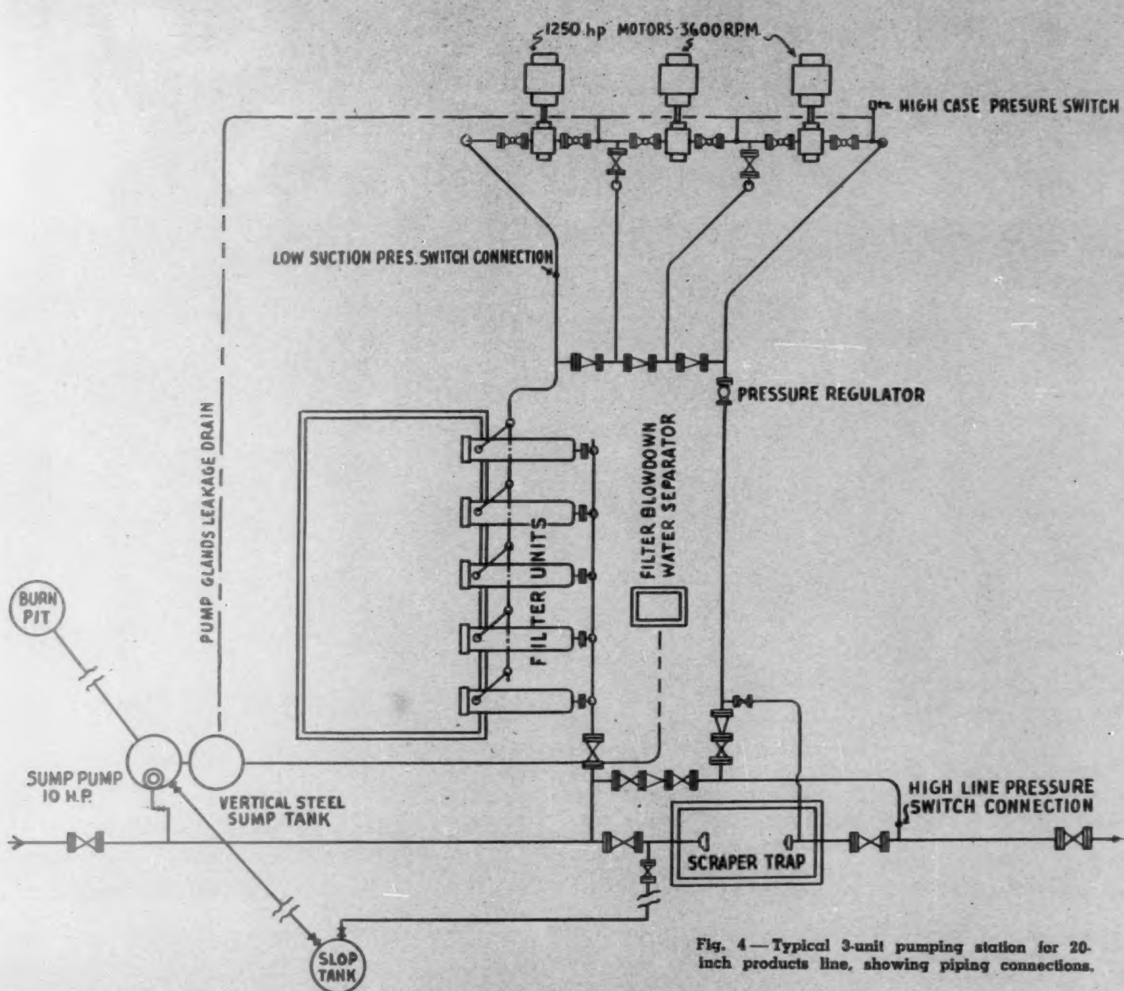


Fig. 4 — Typical 3-unit pumping station for 20-inch products line, showing piping connections.

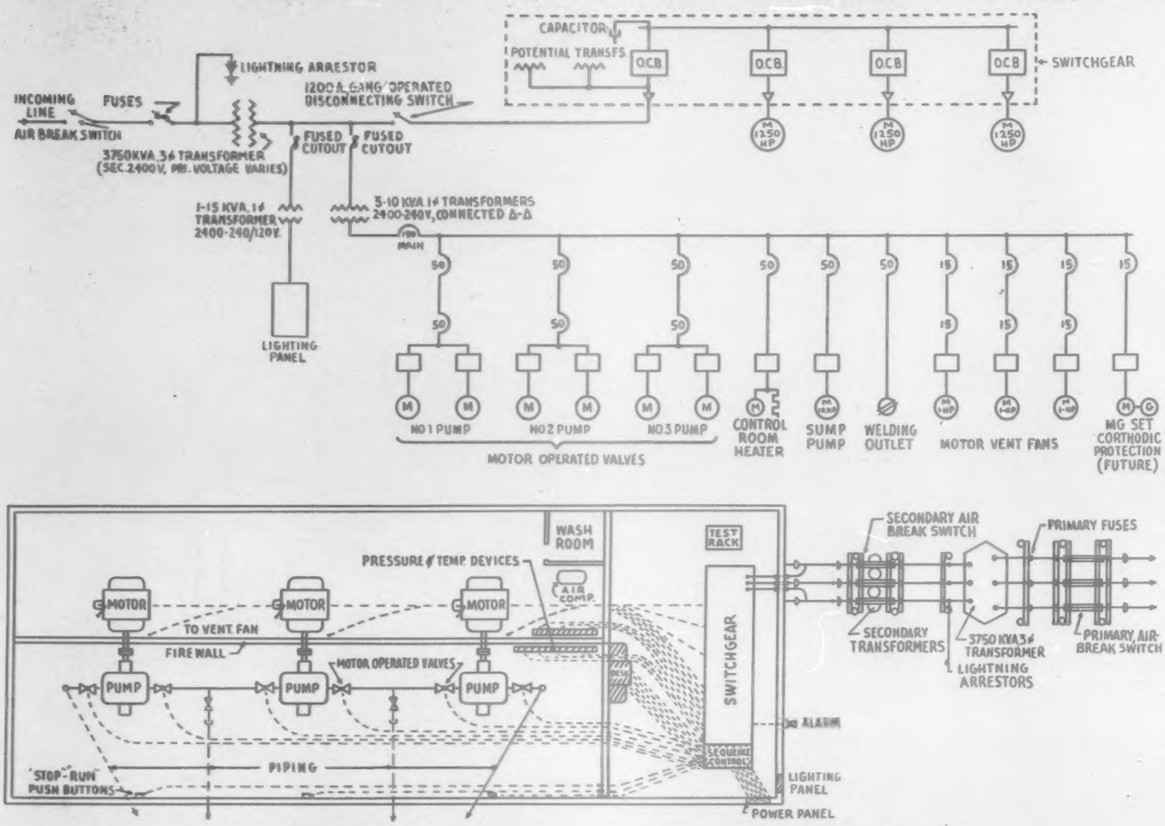


Fig. 5 — One line schematic of wiring and plan of power layout for typical 3-unit pumping station.

Fig. 6 — In a station on the 20-inch products line the three motors are arranged just as in the "Big Inch" stations, with ducts and hoods through which the heated air from the motors is drawn by small exhaust fans mounted in the ducts.

"run-stop" push button can be padlocked in the "stop" position to safeguard mechanics working on the pump.

The motor vent fans are so connected that they are started and stopped automatically with the main pump motors to insure adequate ventilation. The control desk has an indicating light to assure the operator that the motor vent fans are running. An indicating lamp shows whether the control room blower is running to keep the room under positive air pressure.

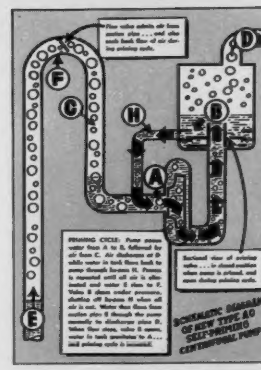
The station layouts shown in these pages are typical, yet they do not apply to any one station. Several items have been rearranged to clarify the layout, and no attempt is made to show the exact location of conduits.

Practically all conduit is below floor level, and it enters a pull box or "pit" under the sequence control cabinet. A cable trench, extending the full length of the switchgear and connecting to the pull box under the sequence control cabinet, simplifies control wiring between these units. All electrical equipment in the pump room, including motor operated valve units, lighting fixtures, and fittings are explosion-proof. Conduit runs from a gaseous area through the firewalls or into the control room have sealing condulets and packing glands. All outside lighting fixtures and those in the motor room are of the vapor-proof type.

Parts of this station design have been used on other pipe lines, and some parts were developed for this particular project. This scheme of station control is expected to minimize the contamination of different products in transit, reduce the costs of operation, and assure continuous delivery of full capacity.

Fig. 7 — Vertical-lift, metal-clad switchgear in each station consists of incoming auxiliary and starting units for each motor.

Self-Priming Pump Uses Revolutionary Spring Valve



A new-type, automatically controlled spring valve enables a recently introduced Type AO automatic, self-priming centrifugal pump to change smoothly from priming or vacuum pumping to straight centrifugal action. Originally a marine development, the revolutionary spring valve principle is now being adapted for general industrial, construction, mining, and farm uses of self-priming pumps.

The Type AO pump is of non-clog design and has two special protective features. A large opening in the impeller permits solids up to one inch to pass through, while a self-cleaning screen protects the valve from being fouled by foreign matter. The pump unit is adaptable to gas engine, steam turbine, or motor drives and, since the self-priming equipment is integral with the pump itself, it is an ideal portable as well as stationary unit.

New V-Belt Sheave Has "Magic-Grip"

A new V-belt sheave, designed for quick and easy mounting and demounting, is being widely applied throughout industry.

Known as the "Magic-Grip" Sheave, it locks to the shaft in one tightening operation. As its tapered split bushing (accommodating normal shaft tolerances) is drawn further into the sheave in mounting, sheave, bushing, and shaft are locked together simultaneously. This positive clamp fit makes sure that the "Magic-Grip" Sheave is perfectly centered and secure, eliminating back-lash and shear.

The new design of the "Magic-Grip" permits sheave to be mounted closer to motor, increasing bearing life by reducing shaft overhang.

For further, more detailed information regarding these new products, write the Editors of ELECTRICAL REVIEW.


58
COTTON MILLS

MOTION STUDY CAN "UP" OFFICE EFFICIENCY 70 PERCENT

Fifty percent efficient office procedures are a wide open field for improvement! The wartime manpower squeeze multiplies the advantages of applying these production-line techniques to office practice.

Harold W. Martin

APPLICATION ENGINEER • ALLIS-CHALMERS MANUFACTURING COMPANY

● Between 1870 and 1940, the number of clerical workers in the United States increased 50 times, while production workers only tripled. Starting with an overwhelming difference between the two categories of workers, there are now relatively similar numbers in both branches of work. During the same period, production increased ninefold. The number of office workers per production worker required by modern industry is more than 16 times that required 70 years ago.

Tremendous war expansion has accentuated this disparity and brought with it production problems not unlike those in the shop.

Pioneering work in motion economy and work simplification, done by such people as Frederick W. Taylor, Frank B. Gilbreth and his wife, Dr. Lillian Gilbreth, has markedly increased the productivity of the production worker. However, motion study principles have not been applied to office procedures to any appreciable extent and the productivity of the office worker has consequently changed little since 1870.

The principles of motion study and work simplification are every bit as applicable to office procedures as they are to production procedures, and (by eliminating lost motion and duplication of effort) they could unquestionably alleviate most office difficulties caused by the present labor scarcity. When it is considered that industrial engineers give most clerical work an efficiency index of approximately 50 percent, the possibilities of improvement become apparent.

Motion study technique

Motion study techniques are the means used to discover Gilbreth's classical "One Best Way" of performing a task. It is possible to analyze scientifically existing procedures and methods of doing specific tasks, and to find ways of eliminating wasted motions and duplicated procedures. Then the remaining motions can be combined and rearranged for a maximum of motion economy and work simplification.

Some office workers' duties require individual initiative and, in that sense, are not necessarily repetitive. Nevertheless, the basic principles of motion economy can often be used by the individual office worker, once the principles are understood. However, most basic office procedures are highly repetitive, and therefore constitute a fertile field for the application of work simplification techniques.

Repetitive office procedures, such as issuing shipping or manufacturing orders and shop specifications, are usually analyzed into individual operations on a "process chart." For highly repetitive motions, as found in the operation of office machinery, collating, etc., operator or operator-machine charts are used. If detailed analysis justifies, micro-motion charts involving detailed motion study of specific operations can be made.

Flow process charts

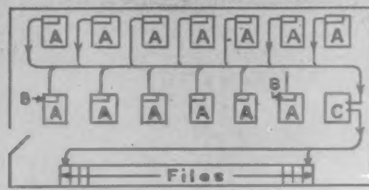
In a process chart, a part, assembly, form, or person is followed through all stages of a procedure. The steps are classified into operations, transportations, storages (or delays), and inspections, all designated by symbols. Wherever possible, distances and times are shown for transportations and storages, respectively. To help in visualizing the flow of work and in revising procedures, a rough layout of the area usually accompanies the process chart.

These five elements cover most conditions of a process chart:

SYMBOL	DESCRIPTION
◯	OPERATION: Indicates work in a given location, such as typing a letter or order, dictating a letter or withdrawing it from a file.
○	TRANSPORTATION: Part or person moves from one place to another.

AT LEFT: In textile mills hard-pressed with the problem of clothing a world at war and producing fabric for countless other needs, special lint-protected motors and V-belt power transmission are counted on heavily for continuous operation through the toughest conditions. Compact units are characteristic. *Robert Yarnall Ritchie photo.*

A Salesmen's Desks
B File Baskets
C File Clerk's Desk



ORIGINAL METHOD

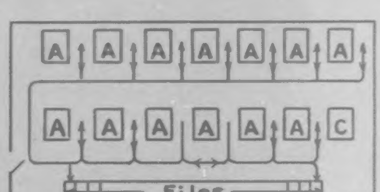
Average Time	Average Distance	Symbol	Description
4 hrs.		▽ 1	In file basket on desk with other letters awaiting collection
	15 ft.	○ 1	Carried to file clerk's desk
.5 hrs.		▽ 2	Awaiting sorting
		□ 1	Examined for general filing location
		○ 2	To pile of letters to be filed in same general location
.5 hrs.		▽ 3	Waits while remainder of letters sorted
	15 ft.	○ 3	Taken with other letters to general filing location
2 min.		▽ 4	Waits while preceding letters filed
		□ 2	Examined for exact filing location
.1 min.		▽ 5	Waits while exact filing location is found
		⊘	Filed in proper location
		▽▽	Remains in file

Summary

Process	Number	Process	Number
"Do" operations	1	Inspections	2
Operations	1	Permanent storages	1
Delays (temporary storages)	5	Average distance traveled.	30 ft.
Transportations	3	Average waiting time	5 hrs.

Fig. 1 — Flow process chart of filing a letter in a sales office — original method.

A Salesmen's Desks
C File Clerk's Desk



ORIGINAL METHOD

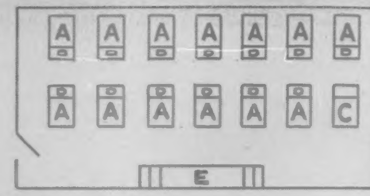
Average Time	Average Distance	Symbol	Description
.2 min.	10 ft.	○ 1	Walks to files from one of desks A
1 min.		○ 1	Locates proper file drawer
.25 min.		○ 2	Opens drawer and locates folder
.25 min.		⊘	Locates and withdraws letter
.1 min.		○ 4	Replaces folder and closes drawer
.2 min.	10 ft.	○ 2	Returns to desk

Summary

Process	Number
"Do" operations	1
Operations	4
Moves	2
Average distance	20 ft.
Average Time	2 min.

Fig. 2 — Flow process chart of salesmen finding current correspondence from file — original method.

A Salesmen's Desks
C File Clerk's Desk
D Current Letter Files
E Non-Current Files



REVISED METHOD

Average Time	Average Distance	Symbol	Description
.25 min.		○ 1	Opens file and locates proper folder
.25 min.		⊘ 2	Locates and withdraws letter
.1 min.		○ 3	Replaces folder and closes drawer

Summary

Process	Number
"Do" operations	1
Operations	3
Moves	0
Distance	0
Time	.6 min.

$$\text{Saving in time} = \frac{2 - 0.6 \times 100}{2} = 70 \text{ percent}$$

Fig. 3 — Flow process chart of salesmen finding current correspondence from file — revised method.

□ INSPECTION: An item, form, or part is inspected or checked for quantity or quality, or, in the case of office forms, to determine course of action.

▽ TEMPORARY STORAGE: Subject is temporarily idle when not being moved, inspected, worked upon, or working. In office procedures, it indicates delays. An example is letter, order, or office form laying in an incoming mail basket awaiting attention.

▽▽ PERMANENT STORAGE: Storage for so long that "temporary" would not apply, such as letter, order, or office form in a file.

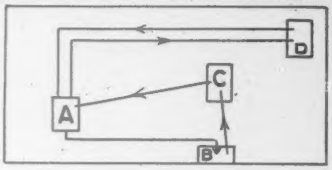
The operations in a given procedure are either "make-ready," "do," or "put-away." Sometimes "do" (productive) operations are identified by shading their symbols with cross-hatch lines.

If similar symbols are consecutively numbered, the total operations, transportations, inspections, and temporary or permanent storages can be easily read. Times or distances indicated on the chart can also be totaled. At the foot of the chart the factors are summarized to simplify comparison of the existing procedure with proposed ones.

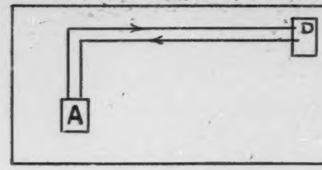
Questioning approach

The process chart is analyzed to find ways of revising the procedure to make it more effective. Here Kipling's "Six honest serving men" are brought into action, first to attack the "do" operations and then the "make-ready" and "put-away" elements. Asking why, what, when, where, how, and who for each individual symbol may be a somewhat lengthy procedure. Actually, the same effect can be had more quickly by analyzing each element for each of these four possibilties:

1. Elimination (what? why?)
2. Combination with other elements (who? how?)
3. Relocation or sequence change (where? when?)
4. Simplification



A Order Clerk's Desk
B Typist's Work Rack
C Typist's Desk
D Duplicator



ORIGINAL METHOD

Average Time	Average Distance	Symbol	Description
2 min.		1	Order clerk dictates revision information to dictaphone
	50 ft.	1	Dictaphone record taken to stenographic work rack
2 hrs.		1	Waits in rack
	15 ft.	2	Record taken to typist's desk and placed in transmitter
.5 min.		2	Duplicator master and carbon obtained and placed in typewriter
1 min.		3	Order revision typed on master
	50 ft.	3	Master and carbon taken to order clerk
15 min.		2	Waits attention
.5 min.		4	Master checked and initialed
	70 ft.	4	Taken to duplicator machine
1 hr.		3	Waits attention
1 min.		5	Required copies run off
10 min.		4	Waits while other orders run off
	70 ft.	5	Copies taken to order clerk
15 min.		5	Waits attention
1 min.		6	Copies routed and mailed

REVISED METHOD

Average Time	Average Distance	Symbol	Description
3 min.		1	Order clerk writes revision information on master and initials
	70 ft.	1	Master taken to duplicator machine
1 hr.		1	Waits attention
1 min.		2	Required copies run off
	70 ft.	2	Copies taken to order clerk
15 min.		2	Waits attention
1 min.		3	Copies routed and mailed

Summary (Revised Method)

Process	Number
"Do" operations	3
Operations	3
Transportations	2
Delays	3
Total distance	140 ft.
Total time	1.5 hrs.

Summary (Original Method)

Process	Number
"Do" operations	4
Operations	6
Transportations	5
Delays	5
Inspections	1
Total distance	255 ft.
Total time	3.75 hrs.

Note: Average lines per order revision — 4.8.

Time saved with revised method — 60 percent

Fig. 4 — Flow process charts for preparation of order revision notice.

Obviously, if a "do" operation can be eliminated, the rest of the procedure is unnecessary. At first thought, this possibility might appear to be extremely unlikely, but, particularly in office procedures, it is surprising how often a procedure is followed only for traditional reasons. Certain forms may be prepared because they have always been prepared, but investigation may prove that some change in another part of the office system has actually made them unnecessary.

Combination has great possibilities. Generally speaking, the fewer the people involved in the issuance of a particular form, the quicker the form can be issued, primarily because delays inevitably occur while the form is awaiting attention.

If an operation cannot be eliminated or combined with some other operation, perhaps it can be performed more advantageously earlier or later in the cycle. It is usually more efficient to combine so far as possible all like operations so that all clerical work is done by one operator, all typing by another, all adding machine work by another, etc. Such relocation of operations has the same general effect as combining two or more operations.

Simplification

Simplification is considered only after the possibilities of elimination, combination, and relocation have failed to give satisfactory results. Simplification of an operation is not actually a part of a process chart survey because it requires detailed motion study. If our six honest serving men have failed to produce improvement, particularly in a highly repetitive operation, then a detailed motion study to find ways of simplifying the operation can be tried. The operation itself is a sequence of events which can be examined for possible elimination, combination, and relocation.

After simplification of the procedure a new process chart is prepared. The possibilities of revising the arrangement of desks, files, and office machinery to give the smoothest flow and shortest distance of transportation should then be studied.

All the implications of a charted procedure must be analyzed. A complete process chart for the filing of

a letter in a sales office is shown in Fig. 1. The charted procedure, of itself, is as simple as could reasonably be expected. But the purpose in filing a letter is to make it as easy as possible to find again. So let us examine this procedure, too (Fig. 2).

Assuming each of the salesmen at the desks "A" is mainly interested in current correspondence from a particular sales area or group of customers, we find 1.4 minutes is spent in going to and from the files and in finding the drawer in which the particular letter is filed. If current correspondence is kept in a file next to each desk, the salesmen will be able to find active letters more quickly and easily. Fig. 3 shows the process chart and layout for the revised procedure, which results in a 70 percent saving in time.

Process vs. product

This example also illustrates two basic factory and office layouts, i.e., process-controlled and product-controlled. In a process-controlled layout, all like processes are concentrated in one location, such as placing all screw machines in one area of a machine shop or doing all stenographic work in one centralized stenographic department.

A product-controlled layout is used in serialized production where all of the machines required to produce a given product are located sequentially. The layout in Fig. 1 is process-controlled, because all filing is concentrated in one place. On the other hand, in Fig. 3, each desk with its related filing cabinet is a product-controlled unit insofar as current correspondence is concerned. In office procedures, analysis often shows that product-controlled layout is more efficient than process-controlled layout.

In assembling process charts, certain mistakes can easily be made. It is essential, particularly in preparing more complex process charts, to avoid confusion of the operator with the part or form. If, for instance, in the preparation of a form the typist left her desk to get carbon paper after the material for typing the form was given her, but before she started typing, a temporary storage of the form would be indicated on the chart. Confusion of the operator with the form would result in a delay being indicated by a small circle, symbolizing the movement of the typist in getting the carbon paper. This would not be correct.

Use of office machinery

Sometimes too much accent is placed on the use of office machinery. A typical example is shown in Fig. 4. The original method required four "do" operations:

1. Dictating the revision information to a dictaphone.
2. Typing the information on a duplicator master.
3. Duplicating the required number of copies.
4. Routing the copies to their destinations.

Obviously the information must emanate from the order clerk, and at first glance there appears to be no possibility of eliminating the first "do" operation or relocating it in the cycle. Then the possibilities of combination with some other operation are considered. The chart shows that considerable delay occurs between dictating the information and typing it on the master. Suppose that the average number of lines

ORIGINAL METHOD

Average Time	Average Distance	Symbol	Description
.3 min.	15 ft.	1	Goes to descriptive specification sheet file
20 min.		1	Withdraws quantity of each sheet required in order they are to appear in specifications, stacking alternate withdrawals crosswise
.1 min.	5 ft.	2	Takes sheets to collation table
20 min.		2	Distributes sheets in sets stacked in order of appearance in specification
.1 min.	5 ft.	3	Goes to file for binders
.1 min.		3	Withdraws binders
.1 min.	5 ft.	4	Returns to collation table with binders
10 min.		4	Inserts sets of sheets in binders
.3 min.	15 ft.	5	Returns to desk with bound specifications
3 min.		5	Clips letters and quotations to bound specifications and places them in mail basket on desk

Summary

Process	Number
Operations	5
Moves	5
Average total distance	45 ft.
Average total time	51 min.

Fig. 5 — Flow process chart of sales engineer issuing quotation specification — original method.

per revision notice was low, perhaps 4 or 5. Then it might be more economical to have the order clerk write the information in longhand on the master sheet instead of dictating it, thus eliminating the second "do" operation. Since speed of issuance is usually a vital factor, elimination of a two-hour average delay would be very desirable.

Eliminating the second "do" operation also eliminates the "make-ready" for the typing operation. Padding the duplicator masters with interleaved carbons saves the order clerk a "make-ready" operation. The inspection and initialing of the typed master, and the delay and transportation between the third (the second "do" operation) and fourth operations are eliminated.

In investigating the fourth "do" operation (operation five of the original method chart), we question the use of a duplicator. This would also be questioned when exploring the possibility of combination of the second and third "do" operations. If the number of copies is too great to permit their preparation during one typing operation, the duplicator method would be necessary. If typing is decided upon, then the operation-inspection step No. 4 would remain unchanged.

A comparison of the summaries of the original and revised methods shows a considerable reduction in the total operations, transportations, delays, and distance

REVISED METHOD

Sales Engineer

Average Time	Average Distance	Symbol	Description
10 min.		1	Prepare specification makeup sheet
.2 min.	10 ft.	1	Takes sheet to clerk
.2 min.	10 ft.	2	Returns to desk
			Sales Engineer performs other specialized duties
3 min.		1	Checks one copy of specifications
3 min.		2	Attaches letters and quotations to specifications and mails

Clerk

Average Time	Average Distance	Symbol	Description
.1 min.	5 ft.	1	Walks to specification sheet file
15 min.		1	Withdraws required number of sheets and stacks them in order indicated on make-up sheet
.1 min.	5 ft.	2	Goes to collation table with sheets
20 min.		2	Distributes sheets on table in sets stacked in order of appearance in specification
10 min.		3	Inserts sheets in binders (binders stacked in rack at back of table)
.2 min.	10 ft.	3	Takes bound specifications to engineer
.2 min.	10 ft.	4	Returns to desk

Summary

Process	Number
Operations	2
Moves	2
Inspections	1
Total time	16.4 min.
Total distance	20 ft.

Summary

Process	Number
Operations	3
Moves	4
Total time	50.6 min.
Total distance	30 ft.

Combined Summary

Combined operations	5
Combined moves	6
Combined inspections	1

Saving in sales engineer's time is about 35 minutes per specification

Fig. 6 — Flow process charts covering the issuing of a quotation specification — revised method.

travelled, which results in a 60 percent saving in time. Eliminating the second "do" operation eases the load in the stenographic department. The first "do" operation with the revised method would take 50 percent longer than originally, but elimination of operation-inspection four cancels half of the increase, resulting in net increase of the order clerk's time of half a minute. This would be more than compensated by the overall saving.

Specialized personnel

Obviously, every effort should be made to spare specialized personnel from simple operations that could be performed more economically by clerks. How quotation specifications might be issued by a sales engineer is shown in Fig. 5. The chart shows little possibility of elimination, combination, or relocation, but perhaps at least some of the work could be performed by non-specialized personnel. If the sales engineer could clearly indicate on a form the composition of the desired set of specifications, they could then be assembled by a clerk (Fig. 6).

From Figs. 5 and 6, it is apparent that there is little or no reduction in the total operations, moves, or overall time of preparation, but delegation of part of the work to the clerk saves over half an hour of the sales engineer's time for every set of specifications prepared. In an office with many sales engineers, the overall saving would be quite appreciable.

The clerk could see that a supply of each specification sheet was always available. With the revised method, the time taken for the clerk to withdraw the required number of sheets is 75 percent of that required by the sales engineer, because the clerk, through more frequent usage, would become more familiar with the locations of the various sheets. An additional saving in the third operation, made by putting the binders in a rack at the back of the collation table, avoids 10 feet of travel to and from the binder file.

These examples show how simple process chart analyses of office procedure can save time and money. The same methods can be just as effectively used to chart more complex procedures, such as the sequence of operations, inspections, moves, and delays, for each of the various copies of a work order. The process chart for such an order would start with an analysis of the preparation of all the copies, and then separate at the point of issue into a number of branches.

(To be continued)

Methods for charting more complete office procedures with branching charts will be described in the second article of this series, in the June issue of ELECTRICAL REVIEW.

ON FOLLOWING PAGES: Machining engine crankshafts is no small job when the shaft weighs 125,000 pounds, as this one does. The workman gives the bearing a smooth finish on a giant lathe.

GET THE MOST FROM VETERAN TRANSFORMERS THIS EASY WAY

Thousands of kilowatts of capacity are hidden inside of transformers already serving power systems! Here is how simple and inexpensive forced-oil cooling can be engineered for these old reliables.

W. C. Sealey

ENGINEER-IN-CHARGE • TRANSFORMER DIVISION • ALLIS-CHALMERS MFG. CO.

● Forced-oil cooling may be applied to existing self-cooled transformers to increase the rating, to older water-cooled transformers to replace worn-out cooling coils, and to modern water-cooled transformers to give additional capacity.

The application of forced-oil cooling to old transformers is similar to designing forced-oil cooling for new transformers. In a forced-oil cooled new transformer the physical size of the core and coils is about 60 percent of that of a self-cooled transformer of the same rating. A design of a self-cooled transformer could be used with forced-oil cooling apparatus and the rating increased 66 percent, but in actual practice several modifications are desirable:

1. More cooling surface for the coils to reduce temperature difference between copper and oil.
2. Reduction of the impedance of the transformer by changing its proportions.
3. Larger bushings and larger tap changers provided for the heavier current.

Transformers already built

Only some of these changes can be made on transformers already built. Increased cooling can be provided for the oil, and larger bushings and tap changers can be installed, if the existing ones are too small for the higher current. The impedance cannot be changed. The area of the cooling surface on the coils cannot be changed.

It is relatively simple to determine the cooling required for a given increased rating of a transformer. For convenience in calculation, the temperature rise of a transformer can be divided into two parts: (1) the temperature rise of the oil above the air or other cooling medium and (2) the temperature rise of the copper hot spot, i.e., the hottest copper, above the oil (gradient). The sum of these two parts is the hot spot copper rise above the ambient temperature. For safe operation, the copper hot spot temperature must be kept at a reasonable value — usually 95 C for continuous operation.

The temperature rise of the copper above the oil increases as load is added to the transformer. For most transformers, the hot spot copper rise above the adjacent oil varies as the 1.6 power of the load. It is impracticable to measure the hot spot copper rise in a commercial test, but the designer can calculate the copper hot spot gradient from experimental data. If this calculated value is not available, a safe assumption for the copper hot spot gradient at full load is:

For forced-air cooled transformers —
$G = 70 -$ (oil rise at full load in degrees C)

For other transformers —
$G = 65 -$ (oil rise at full load in degrees C)

Thermal oil currents

The copper hot spot gradient, that is, copper hot spot rise above oil rise, as a function of the load for various full load copper hot spot gradients is shown in Fig. 1. The hot spot gradient curve is a characteristic of the transformer, and there is no simple means of decreasing it after a transformer has been built. The average copper gradient can be lowered by speeding the flow of oil through the ducts, but even then the oil circulation is likely to be slow somewhere, so that the greatest hot spot gradient in the transformer remains the same.

In a self-cooled transformer, all oil flow is caused by the thermal head from the difference in specific gravity of the warm oil inside the tank and the cool oil in the radiators. This thermal head overcomes the friction to the flow of oil through the radiators and coil ducts.

When forced oil circulation is added to a self-cooled transformer, the oil pump overcomes all friction external to the tank. The thermal head has to overcome only the friction in the coil ducts. The thermal head adjusts itself, as in all similar cases of natural convection, to equal the friction head in the coil ducts. The result is a slightly smaller hot spot correction between average copper temperature and hot spot copper, but the value of the hot spot gradient will not be affected.

Heat exchanger limitations

The factor which can be changed is the oil rise above cooling medium. This can be done by providing additional cooling for the oil. The lower the oil temperature, the higher can be the copper gradient without exceeding a 65 C hot spot rise. A 65 C copper hot spot rise is the temperature rise which in a 30 C ambient air temperature will produce a hot spot temperature in the copper of 95 C. This 95 C ultimate is generally assumed to be the safe limit for continuous loading.

The most efficient, commonly used method of cooling oil is circulating it by means of a pump through an external oil-to-air or oil-to-water heat exchanger. The size of coolers required increases rapidly as the permissible oil temperature rise above ambient is decreased. To keep the coolers reasonable in size, it is seldom practical to design for an oil temperature rise of less than 20 C.

The basis for applying forced-oil cooling to old transformers should be the tested or calculated oil rise, and the calculated hot spot copper rise data which the manufacturer of the transformer can supply. When the full load hot spot copper gradient is known, the permissible oil rise for the desired load may be read from Fig. 2.

The power to be dissipated at a given load is:

$$K = \text{core loss} + \left(\begin{matrix}\text{copper loss}\\ \text{at full load}\end{matrix}\right)\left(\frac{\text{actual load}}{\text{full load}}\right)^2$$

The forced-oil cooling equipment must have capacity to dissipate this kilowatt loss with an oil rise not exceeding the value obtained from Fig. 2. The quantity of oil circulated is generally between one and two gallons per minute for each kilowatt of loss dissipated. This results in a difference between hot oil and cold oil of from 5 C to 10 C.

Example

GIVEN: A self-cooled transformer has these characteristics:

No-load loss — 42 kw (from test).

Copper loss at full load — 95 kw (from test).

Oil rise at full load—45 C (from test or calculated).

Hot spot copper rise at full load — 65 C (65 C assumed or value from manufacturer).

REQUIRED: Size of cooler necessary for 150 percent continuous load.

SOLUTION: Hot spot gradient = (hot spot copper rise at full load) − (oil rise at full load) = 65 C − 45 C = 20 C.

$$\text{Total loss} = \text{no-load loss} + (\text{copper loss})\left(\frac{\text{actual load}}{\text{full load}}\right)^2$$
$$= 42 + 95 \times (1.5)^2 = 256 \text{ kw.}$$

The cooler must be large enough to dissipate 256 kw with a top oil rise of 27 C (from Fig. 2). The quantity of oil circulated will be between 256 and 512 gpm, based on one to two gallons per minute for each kw of loss.

If forced-oil cooling is added to a self-cooled transformer, with the radiators remaining in place, the self-

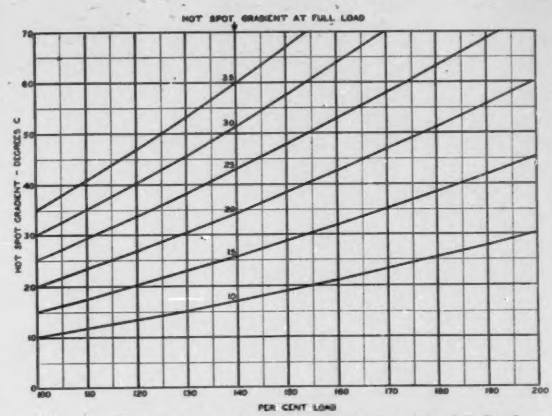


Fig. 1 — Copper hot spot gradient variation with full load.

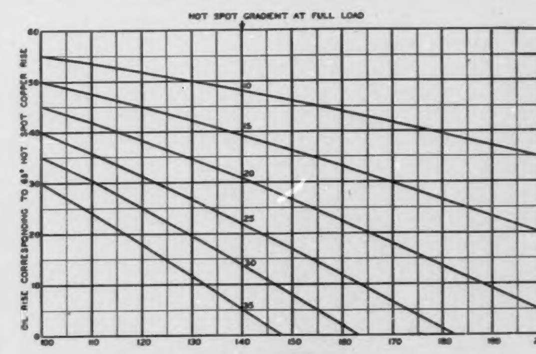


Fig. 2 — Maximum allowable oil rise at increased load when hot spot copper rise is to remain at 65 C.

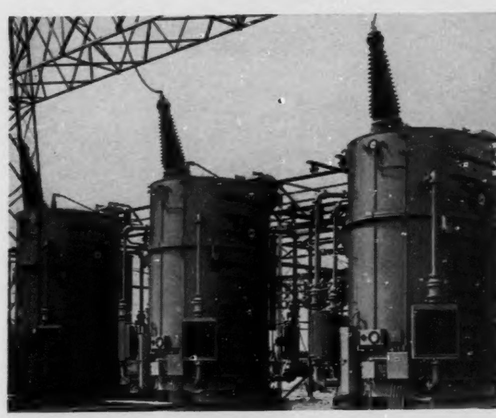


Fig. 3 — These single-phase, forced-oil cooled transformers are each rated 25,000 kva, 220,000 volts to 13,800 volts.

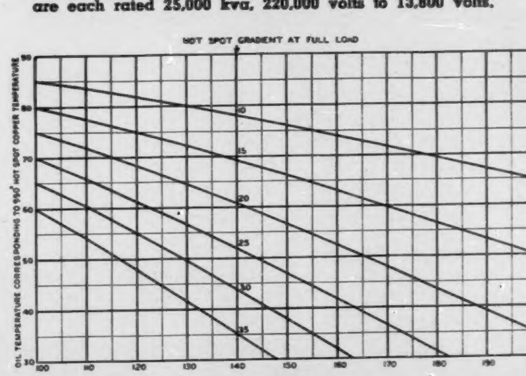


Fig. 4 — Maximum oil temperature allowable at increased loads when copper hot spot temperature is not to exceed 95 C.

cooled rating will not be changed. With both the radiators and the forced-oil cooling in operation, the forced-oil circulation will modify the natural oil circulation and decrease its efficiency. This effect has only slight importance since in most cases the heat dissipating capacity of the forced-oil cooling is several times that of the self-cooled radiators. Similarly, when water cooling and forced-oil cooling is employed, the effectiveness of the water cooling coils is reduced.

Types of forced-oil cooling

There are two types of forced-oil cooling. One has a centralized cooler, mounted either on the tank or nearby, through which all the cooling oil is circulated by one or more pumps. The second type (Fig. 3) has a number of individual independent coolers, each consisting of a pump and heat exchanger. One advantage of the individual unit cooler is the simplicity of the piping connections, which support the cooler and thus eliminate the necessity of flexible joints for taking care of expansion and misalignment of the pipe. Also, if one cooler is shut down for any reason, the remaining coolers will run independently and the transformer can continue in operation at slightly reduced rating.

When forced-oil coolers are applied to self-cooled transformers, the radiators may be removed and the forced-oil cooling equipment can be mounted on the radiator flange connections. Sometimes the existing valve connections may be used for supporting forced-oil cooling equipment. Where neither of these can be used, standard radiator valves can be welded on the tank for mounting the forced-oil cooling equipment. The top connection which draws oil from the tank should be at least one foot below the oil level of the transformer to avoid aeration of the oil. Baffles can also be used to prevent aeration where the top connection must be less than one foot below the oil level.

When forced-oil cooling equipment is applied to an old transformer, it is necessary to check the current-carrying capacity of the bushings, tap changers, terminal boards, the temperature rise of the cover, etc. In some cases these factors limit the increased current which can be carried, and often new bushings are necessary. In some cases soldered connections in the windings form a limitation. Associated equipment, such as cables, reactors, circuit breakers, disconnecting switches and current transformers, may limit the overload which can be carried when forced-oil cooling is applied.

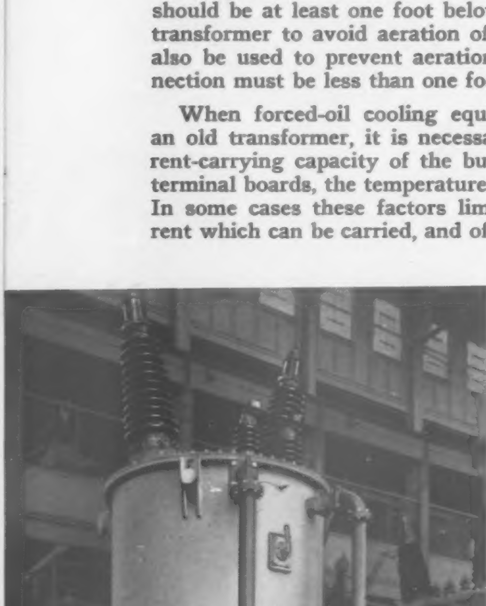


Fig. 5—A smaller transformer has forced-oil cooling. The new rating of this single-phase unit is 1,667 kva, 97,700 to 6,600/13,200/22,800 volts.

Overloading forced-oil cooled units

When forced-oil cooling equipment has been installed on a transformer, the unit may be loaded by temperature control, using the same principles as for self-cooled transformers.

The safe operating temperatures of the hot spot copper for a forced-oil cooled transformer are the same as for any other type of transformer. For recurrent loads, the hot spot copper temperature should not exceed 95 C for 24 hours, or 105 C for an 8-hour period, or 110 C for a 2-hour period in any one day. The hot spot copper rise is equal to the top oil rise as read by a thermometer in the hot oil, plus the gradient from the proper curve (Fig. 1). Fig. 4 shows allowable oil temperatures for 95 C hot spot copper temperature.

In determining the continuous safe overloads for self-cooled transformers to which forced-oil cooling has been added, it is generally safe to increase the forced-oil kva load by the same increase in kva (not percent) which would apply to the same transformer if still operated as self-cooled. For example, a 2,000 kva self-cooled transformer, rated 3,000 kva forced-oil cooled, could be overloaded (ASA standards C57.3) 1 percent of 2,000 kva or 20 kva, for each degree C that the ambient temperature is below 30 C. If the ambient temperature were 22 C, the allowable continuous load would be:

$$\text{Load at } 22\text{ C} = 3{,}000 + 8 \text{ percent of } 2{,}000$$
$$= 3{,}000 + 160, \text{ or } 3{,}160 \text{ kva.}$$

Other recommendations for overloading can be applied in similar manner, using the self-cooled rating as the base for calculating overloads.

Future for forced-oil cooling

One of the disadvantages of forced-oil cooling is that the power losses in the transformer at its increased rating will be higher than the losses in a new transformer of the same kva rating. The power required for the coolers also reduces the overall efficiency of the transformer. The impedance drop is greater. Some maintenance is required. These factors would be evaluated in normal times in determining whether to use forced-oil cooling for cooling a transformer.

The advantage is that increased kva capacity is obtained with the use of relatively little additional material.

In war time, when conservation of critical materials is essential, forced-oil cooling of both new and old transformers provides a noteworthy contribution toward conserving material. Even during peace there will be many cases where its application to both old and new transformers is desirable.

AT RIGHT: The 6-and-30 degree V-angles of a commutator bar are machined on this boring mill. This operation on the assembled bars and mica takes place between the various seasoning cycles which are considered so important a phase of commutator fabrication.

IT'S SIMPLE TO OVERLOAD TRANSFORMERS SAFELY—IF YOU KNOW HOW

Transformer design formulas usually look complicated. However, big formulas make simple curves . . . and anyone can read values off curves like these for simple computation of overload temperature rises.

Harding B. Hansen

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

● While the temperature rise of a transformer carrying a variable load can be calculated only through the use of rather involved equations, it is possible in many ways to reduce the amount of work necessary. The following procedure eliminates all extraneous factors producing a simple and speedy method of calculating approximate temperature rise.

The American Standards Association (Standard C-57) has recommended certain safe temperatures which form a convenient guide:

(a) ***Temperature Maintained Continuously.*** When the temperature is maintained continuously, the limit suggested is

Hottest-spot temperature 95 C

(b) ***Temperature from Recurrent Short-time Overload Operation.*** A recurrent short-time overload is one of limited duration that is imposed according to a known schedule; it is regarded as occasional and not occurring oftener than about once every 24 hours. The limits suggested are

Time in any 24-hour period	2 Hrs.	8 Hrs.	24 Hrs.
Hottest-spot temperature	110 C	105 C	95 C

(c) ***Temperature from Emergency Short-time Overload Operation.*** An emergency short-time overload is an unexpected overload of limited duration; it is to be regarded as an infrequent occurrence. The limits suggested are

Time of emergency load	2 Hrs.	8 Hrs.	24 Hrs.
Hottest-spot temperature	115 C	110 C	105 C

All curves presented are plotted with linear rectangular coordinates, and everything is reduced to its simplest form. The only data required for these temperature rise calculations is that taken from the nameplate and from the usual commercial tests.

In solving a transformer heating problem, four definitions are often referred to:

1. The *oil temperature* rise is the rise of the top oil above the ambient temperature.
2. The *copper gradient* is the difference between the hot-spot copper temperature and the top oil rise.
3. The *ultimate temperature rise* will be reached if a constant load is maintained long enough for the temperature to become constant.
4. "T" is the *thermal time constant* and is numerically equal to the time which would be required to reach the ultimate temperature if all the heat were stored and none dissipated by the cooling surface. How to calculate "T" will be shown later.

Ultimate rise

It has been found from many tests that the ultimate oil rise for self-cooled and water-cooled transformers varies approximately as the 0.8 power of the total loss. Fig. 1 gives values of "K" for the determination of the ultimate oil temperature rise for various loads in transformers having copper-over-iron loss ratios of one, two, three, and infinity. To find the ultimate oil temperature rise it is only necessary to select the required load on the abscissa, follow it up to the proper copper-over-iron-loss ratio (taken at 100 percent load) curve and read the factor "K." The product of "K" and the ultimate oil temperature rise at 100 percent load is the ultimate oil rise for the particular load.

In forced-air and forced-oil-cooled transformers, the ultimate oil temperature rise varies as the first power of the total loss, and requires different (Fig. 2) curves. The procedure for finding the ultimate oil rise is the same as for self-cooled transformers.

It has been found that for oil-immersed transformers, the copper gradient varies approximately as the 1.6 power of the load. Fig. 3 gives values of copper gradients for various full load gradients. To find the copper gradient, select the required load on the abscissa, follow it up to the proper full-load copper gradient curve and the answer can be read from the ordinate scale.

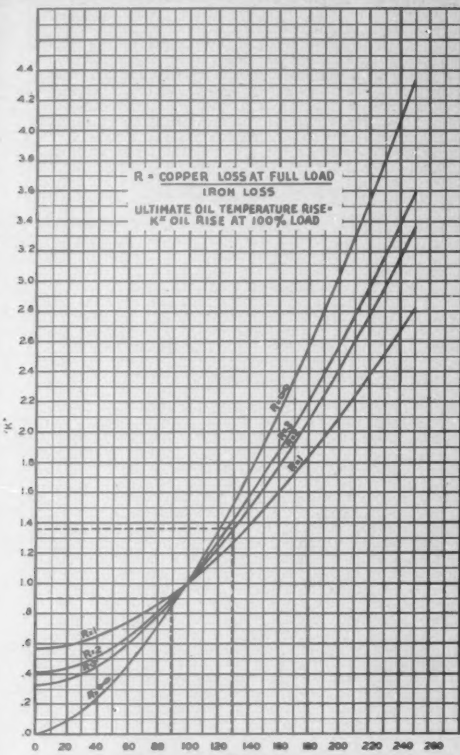


Fig. 1 — Ultimate oil temperature rise for self-cooled and water-cooled transformers.

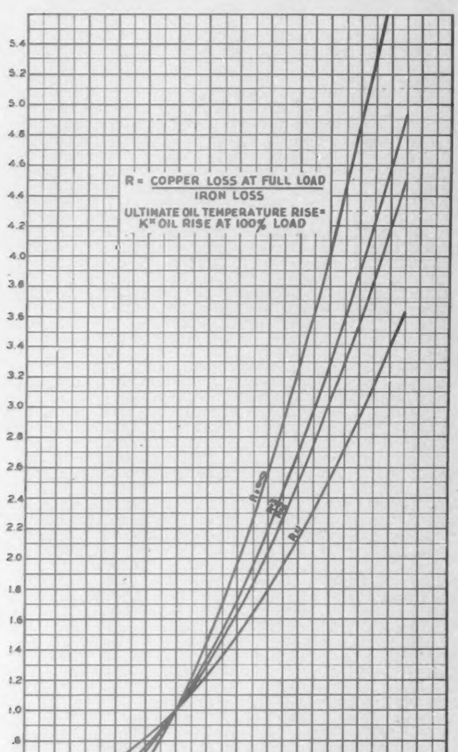


Fig. 2 — Ultimate oil temperature rise for forced-oil cooled and forced-air cooled transformers.

Heating, cooling curves

Curves giving oil temperature rise and oil cooling for various ultimate oil temperature rises in self-cooled and water-cooled transformers having thermal time constants of 2, 4, 3, and 6 are shown in Figs. 4 and 5. Figs. 6 and 7 of the appendix give similar curves for forced-air and for forced-oil-cooled transformers. However, the curves in Figs. 4 and 5 can be used for forced-air and forced-oil-cooled transformers with only small error. The first hour is on an expanded scale to give the curves better readability. All cooling curves begin at an oil temperature rise of 100 degrees. This is permissible because, when the transformer begins to cool, the transformer cannot tell where the curve begins. The only result of starting all curves at 100 C is that the point on the curve where the transformer starts to cool is usually at some time other than zero.

It may be asked why a thermal time constant is necessary for arriving at the oil temperature rise and not for the copper gradient. The copper reaches its ultimate temperature much faster than the oil and therefore the time element can be considered negligible.

The thermal time constant can be calculated from

$$T = \frac{UH}{W}$$

T = Thermal time constant in hours.

U = Ultimate temperature rise of oil over ambient.

H = Thermal capacity of complete transformer, or 0.058 x (lbs. core and coils) + 0.040 x (lbs. case) + 1.33 x (gal. oil).

W = Total watts loss at any given load.

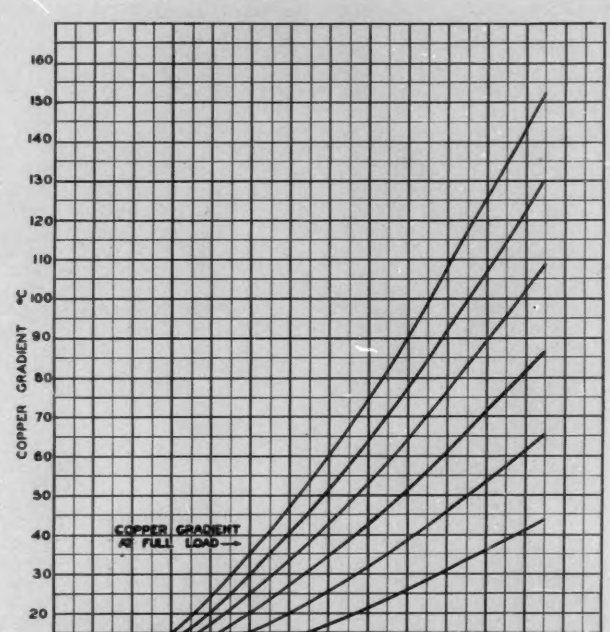


Fig. 3 — Copper gradient curves for different full load gradients.

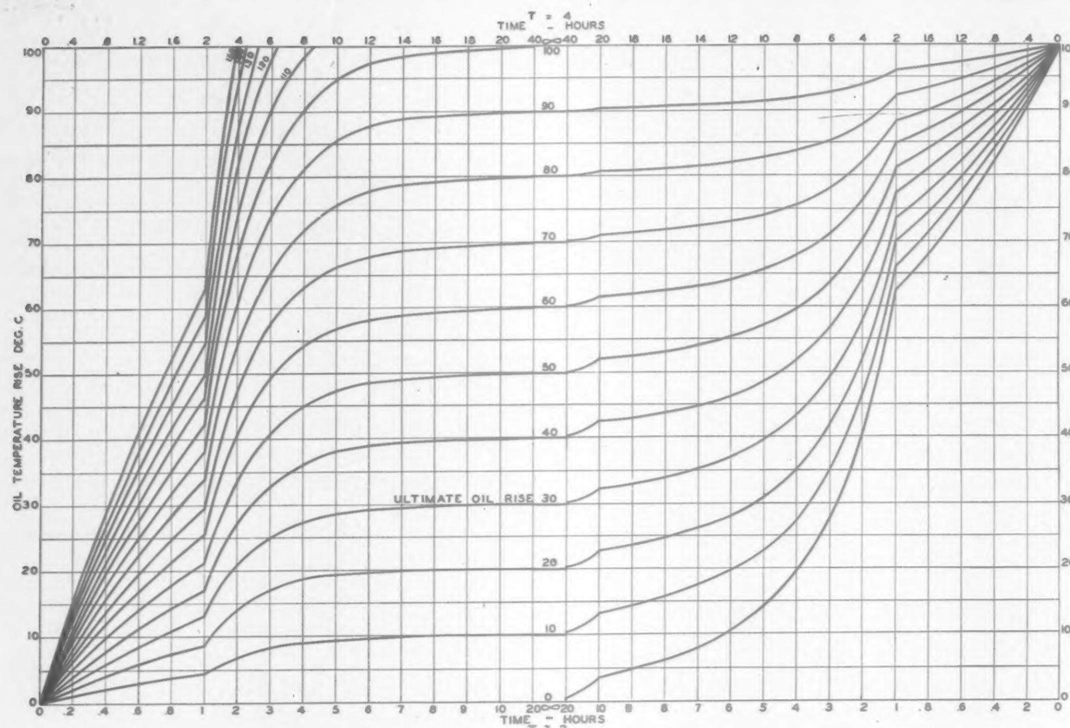


Fig. 4 — Oil temperature rise versus time in hours for self-cooled and water-cooled transformers, where T equals 2 and T equals 4 hours.

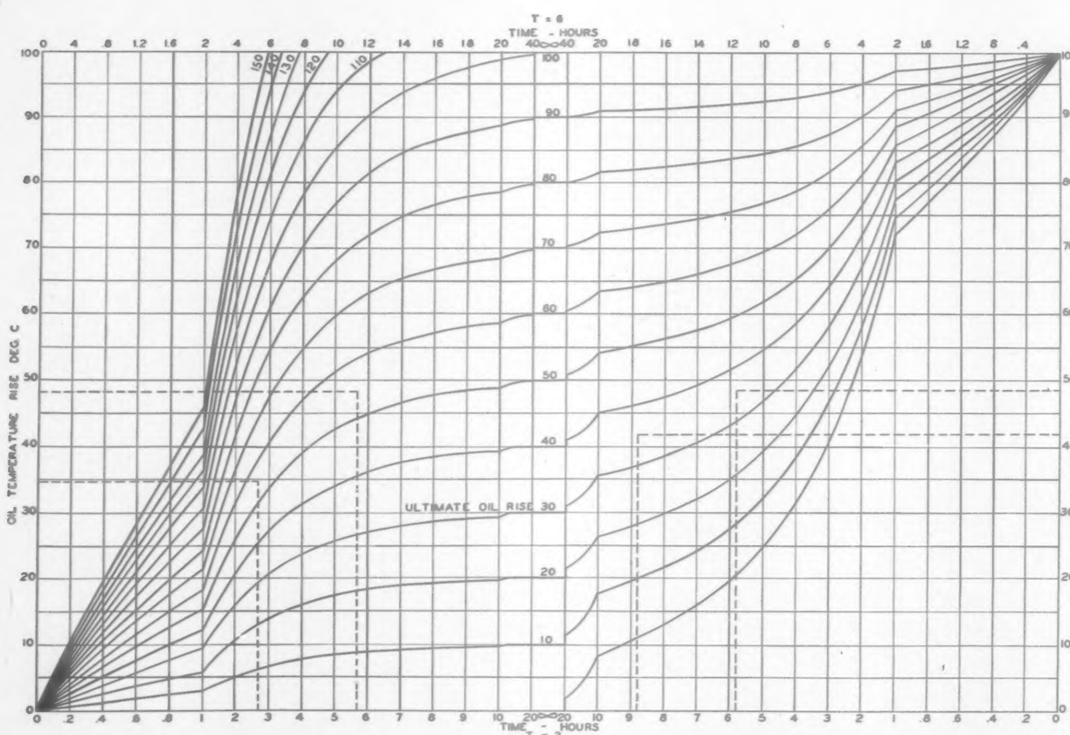


Fig. 5 — Oil temperature rise versus time in hours for self-cooled and water-cooled transformers, where T equals 3 and T equals 6 hours.

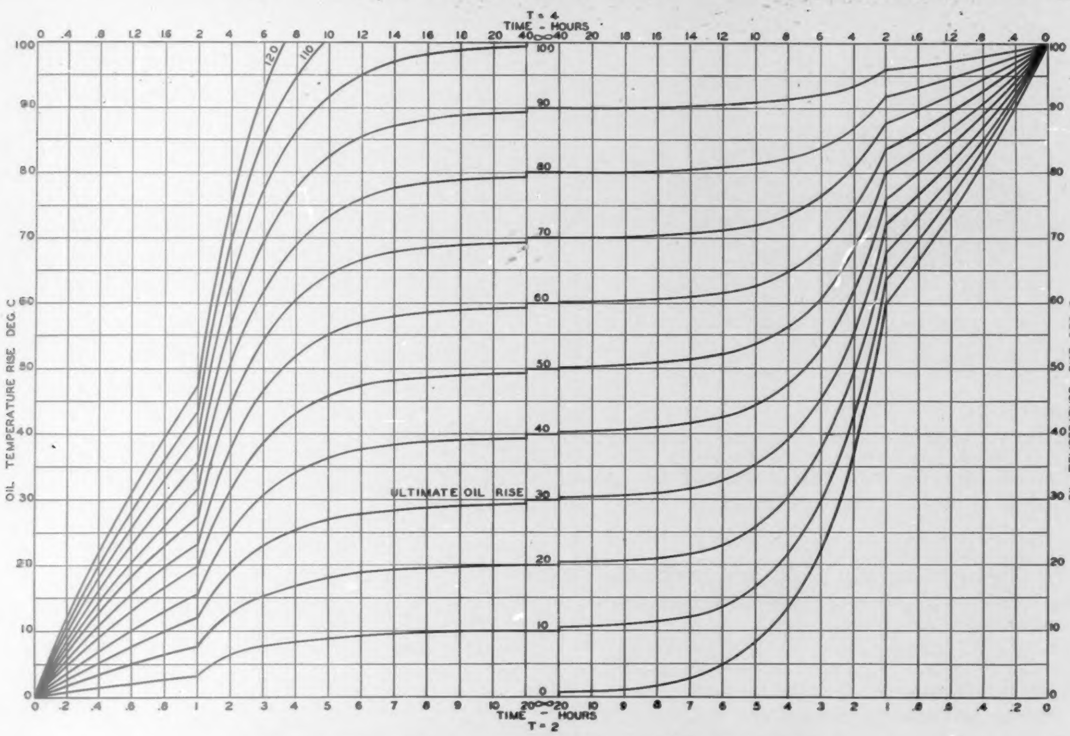


Fig. 6 — Oil temperature rise versus time in hours for forced-oil cooled and forced-air cooled transformers, where T equals 2 and T equals 4 hours.

Example

(a) Assume that it is necessary to load a self-cooled transformer at 130 percent load for three hours. The oil temperature gauge on the transformer reads 60 C. Assume a 25 C ambient temperature. What is the hot-spot temperature at the end of three hours?

(b) If 90 percent load is carried for three hours after the load in (a), what is the temperature after the second three hours?

The self-cooled transformer under question has the following characteristics as taken from the nameplate and the commercial test:

Core loss — 13,000 watts by test.

Copper loss at full load and 75 C — 26,000 watts by test.

Oil temperature rise with continuous full load — 40 C by test.

Copper temperature rise at full load by resistance — 45 C by test.

Weight of core and coils — 20,000 lbs. from nameplate.

Weight of case—11,000 lbs. from nameplate.

Quantity of oil — 1,400 gals. from nameplate.

Some form of table such as Fig. 8 will simplify the solution and eliminate errors. All the known data can be entered and the calculations can be filled in as they are made.

Solution to (a) — The weights are written in the table and the total thermal capacity is calculated. The core loss, copper loss, total loss, oil rise, and hot-spot or copper gradient at 100 percent load are entered in the table. The copper gradient for this transformer is 45 C+10 C−40 C=15 C.

The initial oil temperature rise will be 60 C as read on the thermometer minus 25 C ambient.

60 C−25 C=35 C initial.

The copper-over-iron loss ratio for this transformer at full load is $\frac{26{,}000}{13{,}000}=2$. The constant, "K," for 130 percent load will be 1.36 (Fig. 1). The ultimate oil temperature rise is 1.36 x 40=54.4.

The time constant for 100 percent load is

$$T=\frac{UH}{W}=\frac{40 \times 3{,}460}{39{,}000}=3.55 \text{ hours.}$$

The T at 100 percent load can be used throughout the problem. However, if greater accuracy is desired, the procedure outlined in the appendix can be used. Let us consider T=3 for this problem. This will give a higher oil rise than T=4 and therefore be on the safe side, although the error will be only slight.

To get the oil temperature rise after three hours for T=3, refer to Fig. 5. The initial oil temperature rise is chosen on the ordinate (35 C in this problem) and is followed to the proper ultimate oil temperature rise curve. In this case the ultimate oil temperature rise is 54.4 degrees, which is approximately half-way between the 50 and 60 degree curves. From that point to the abscissa gives a starting time of 2.7 hours. After the three hours, the time on the abscissa will be 2.7+3 or 5.7 hours. From the 5.7 hour point to a point mid-way between the 50 and 60 degree curves gives an oil temperature rise of 48.5 degrees. This is the oil temperature rise after three hours for T=3.

Copper gradient

The copper gradient (Fig. 3) at 130 percent load, with a 15 degree gradient at full load, is 22.5 degrees.

The final hot-spot temperature after three hours will be the oil rise plus the copper gradient plus the ambient temperature, or

$$48.5\ C + 22.5\ C + 25\ C = 96\ C$$

If this overloading comes under classification (b) recurrent, short time overload of the A.S.A. recommendations, then it is a safe load.

Solution to (b) — The procedure followed is the same for the cooling curves as in the heating curves.

The ultimate oil temperature rise of 90 percent load (Fig. 1) is

$$.90 \times 40\ C = 36\ C$$

The initial oil temperature rise is now 48.5 degrees. If the thermometer reading is different, then it should be used as the initial temperature.

For T=3 (Fig. 5) with an initial rise of 48.5 degrees and a 36 degree ultimate oil temperature rise, the starting point for 90 percent load will be 5.8 hours. After three more hours or a total 8.8 hours, the oil rise will drop to 42 C.

The copper gradient for 90 percent load (Fig. 3) will be 12.6 C.

The final hot-spot temperature after three hours of cooling with 90 percent load is $42\ C + 12.6\ C + 25\ C = 79.6\ C$.

The procedure for forced-oil and forced-air-cooled transformers is the same. The only difference is that Fig. 2, and, for greater accuracy, Figs. 6 and 7 should be used.

The labor involved by the use of this method for finding temperature rises is cut to a minimum, but a high degree of accuracy is still maintained.

Appendix

For greater accuracy for the problem given, this procedure may be used:

(a) The core loss will remain constant at all loads; the copper loss varies as the square of the load. Therefore, at 130 percent load the copper loss will be $\left(\frac{130}{100}\right)^2 \times 26{,}000 = 44{,}000$ watts. The total loss at 130 percent load will be the core loss plus the copper loss or $13{,}000 + 44{,}000 = 57{,}000$ watts.

T for 130 percent load is

$$T = \frac{UH}{W} = \frac{54.4 \times 3{,}460}{57{,}000} = 3.3 \text{ hours.}$$

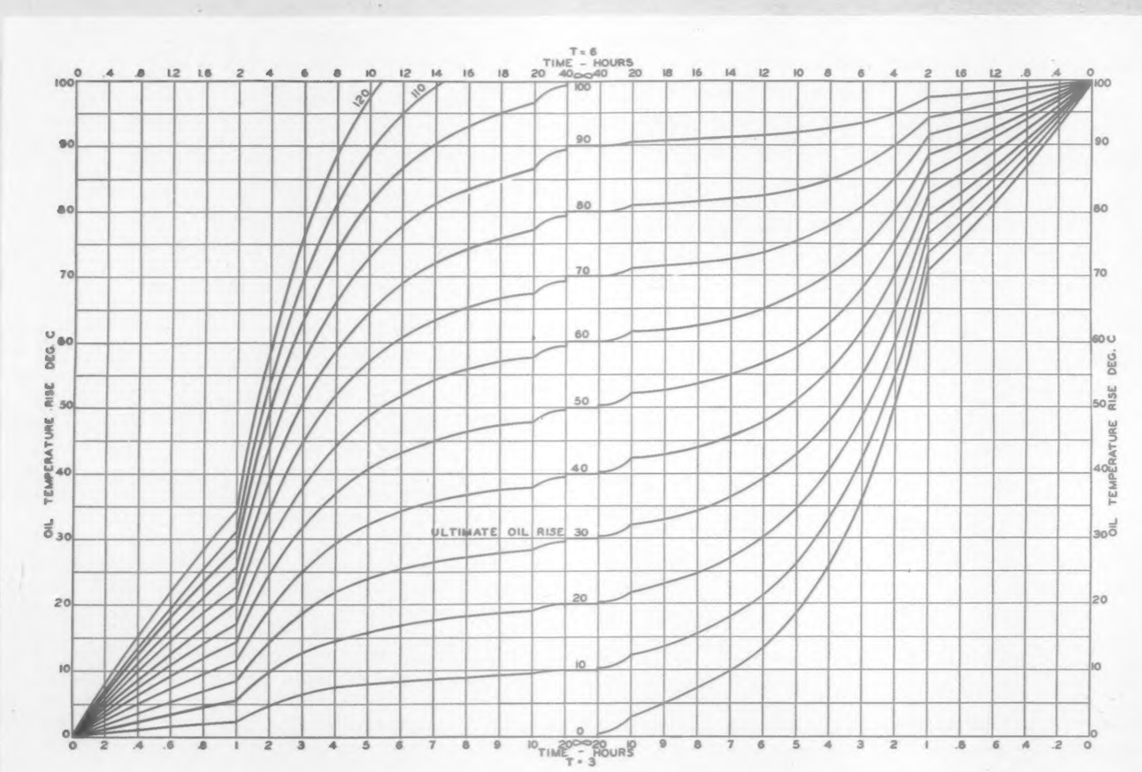


Fig. 7 — Oil temperature rise versus time in hours for forced-oil cooled and forced-air cooled transformers, where T equals 3 and T equals 6 hours.

In order to get the oil temperature rise after three hours, it will be necessary to interpolate between the curves T=3 and T=4. For T=3 (Fig. 5) the oil temperature rise is 48.5 as shown before. For T=4 (Fig. 4) by the same procedure, the zero time at an initial of 35 C is 3.6 hours. The final time of 3.6+3, or 6.6 hours, gives an oil temperature rise of 46.5 degrees. The problem has a T of 3.3. Therefore the oil temperature rise will be somewhere between 48.5 and 46.5 degrees or approximately 47.9 degrees.

The copper gradient (Fig. 3) is 22.5 degrees.

The final hot-spot temperature after three hours will be 47.9 C+22.5 C+25 C=95.4 C.

(b) At 90 percent load the copper loss is $\left(\frac{90}{100}\right)^2$ x 26,000=21,000 watts. The total loss is 13,000+21,000=34,000 watts.

$$T=\frac{36 \times 3{,}460}{34{,}000}=3.66 \text{ hours.}$$

It is again necessary to interpolate between the T=3 and T=4 cooling curves. For T=3 (Fig. 5) with an initial of 47.9 degrees and a 36 degree ultimate oil rise, the oil rise will be 42 degrees. For T=4 with the same constants the oil temperature rise will be 43 degrees. Thus the oil temperature for T=3.66 will be about 42.7 degrees.

The final hot-spot temperature after cooling three hours with 90 percent load is 42.7 C+12.6 C+25 C=80.5 C.

From this it is apparent that only a very small error was introduced by the assumption that T=3 for the entire problem.

L. core and coils	$20{,}000 \times .058 = 1{,}160 = H_1$
Lb. case	$11{,}000 \times .040 = 440 = H_2$
Gal. oil	$1{,}400 \times 1.33 = 1{,}860 = H_3$
Total thermal capacity	$= H_1 + H_2 + H_3 = 3{,}460 = H$

Percent load	100	130	90	Given
Watts core loss	13,000			Given
Watts copper loss at 75 C	26,000			Given
Watts total loss	39,000			Given
Hours elapsed		3	3	Given
Initial oil temp. rise		35	48.5	Fig. 5 and Given
K	1.00	1.36	0.90	Calculated
Ultimate oil rise	40	54.4	36	Fig. 1
T	3.55			Calculated
Copper gradient	15	22.5	12.6	Fig. 3
Oil rise at end of elapsed time	40	48.5	42.0	Fig. 5
Ambient	25.0	25.0	25.0	
Hot-spot temperature rise	80.0	96.0	79.6	Calculated

Fig. 8 — Table for recording thermal characteristics and calculating temperature rise of a transformer.

WHAT'S THE ANSWER?

Question— We need a new source of direct current in our machine shop. Would a mercury arc rectifier be suitable for furnishing 125 kw at 125 volts direct-current for this purpose? R. M. C.

Answer— Mercury arc rectifiers are rated in amperes rather than kilowatts. A rectifier rated 1,000 amperes at 125 volts would also be capable of furnishing 1,000 amperes at any reasonable d-c voltage. The rectifier itself will therefore cost about the same whether used at 125 volts or 250 volts. The rectifier transformer, on the other hand, would be rated at 125 kw. The combined cost will be quite high when compared with an equivalent 125-volt motor-generator set.

Furthermore, a 125-volt rectifier will also be less efficient than an m-g set. As the arc drop is independent of the supply voltage and a function of only the direct-current, the losses in the rectifier will be the same for 1,000 amperes at 125 volts as they would be for 1,000 amperes at 250 volts or any other voltage. The useful kw output, on the other hand, is proportional to the d-c voltage and therefore the efficiency will decrease as the voltage is lowered.

For d-c voltages below 250 volts the motor-generator set is generally more economical.

Question— We have two transformers of 5 and 3 kva with impedances of 2.9% and 2.3% respectively. How will a total load of 8 kva divide between the two units when they are paralleled? L. J. C.

Answer— The ratio of resistance to reactance should be known, but any error introduced by this factor is generally negligible with the following formula:

% of total load carried by transformer No. 1 =

$$\frac{\dfrac{\text{KVA of No. 1}}{\text{\% Z No. 1}}}{\left(\dfrac{\text{KVA of No. 1}}{\text{\% Z No. 1}} + \dfrac{\text{KVA of No. 2}}{\text{\% Z No. 2}}\right)} \times 100 =$$

$$\frac{\frac{5}{2.9}}{\frac{5}{2.9}+\frac{3}{2.3}} \times 100 = \frac{1.72}{1.72+1.30} \times 100 = \frac{1.72}{3.02} \times 100 =$$

57% or 4.56 kva

It follows transformer No. 2 carries 43% of the total load or 3.44 kva.

"What's the Answer?" is conducted for the benefit of readers of ELECTRICAL REVIEW who have questions on central station, industrial or power plant equipment. Send all questions to the Editors of ELECTRICAL REVIEW.

THE NINETEEN BASIC U. S. INVENTIONS

IV. MODERN LIVING*

Where would civilization be without incandescent lights, induction motors, motion pictures, phonographs, aluminum, and plastics? Not luck, but intense, costly research produced these important inventions.

Miles Henninger

PATENT ATTORNEY • MILWAUKEE, WISCONSIN

● We come now to two great electrical inventions which preceded De Forest's amplifier tube and were of even more general interest. These inventions were Edison's incandescent electric lamp and Tesla's induction motor.

Edison's Incandescent Lamp 1880

Thomas A. Edison came from a family which up to his time had not displayed signs of exceptional ability. Edison, however, at the age of eleven already began accumulating apparatus for a chemical and physics laboratory at such rate that he found his allowance inadequate by the time he was fifteen. Then he persuaded his parents to let him sell newspapers on the Grand Trunk Railway between Port Huron and Detroit. After a disastrous fire in the baggage car started by one of his experiments, Edison was forcibly graduated from the newsboy job and became a telegraph operator. While still a very young man, he invented a multiple telegraphic stock ticker, on which he easily sold the patent for many times his estimate of its value. From then on his life work was set.

Edison had no formal technical training, but he did have close contact with current mechanical and electrical problems. One of Edison's first inventions was a voting machine which politicians did not want, which the public did not demand, and which was a flat failure. Thereafter, Edison surveyed the probable demand, the probable cost of development, and the probable profit before undertaking a project. Nevertheless, he lacked the kind of patience and skill required to run a manufacturing and selling organization, and he was totally uninterested in finance. Consequently, Edison personally received only a small fraction of the return obtainable from his various basic inventions, although the amounts received were enough for his needs and, more important to him, they maintained his well-equipped and well-staffed laboratory.

The incandescent filament lamp is the most important Edison invention and it well demonstrates his method of approach, which called for infinite care and great energy over long periods of time, and for courage in spending money on new ideas. Edison spent about $40,000 before he could produce the first incandescent lamp and he spent $100,000 in finding the best natural fiber for the filament. Electric arc lamps were well known, but they were not suitable for indoor use. The problem of "subdividing the electric light" was widely discussed and its answer had been sought by many persons before Edison supplied a practical solution.[1]

Edison saw the problem as a possible boon to humanity, as a challenge to his ingenuity, and as a likely satisfactory supply for a large commercial demand. The nearest approach to an electric lamp was a device patented by Sawyer and Mann, in which a transparent evacuated bulb contained a thin U-shaped carbon rod connected to wires leading in from the exterior of the bulb. The Sawyer and Mann lamp was impractical because it used large amounts of current to produce only a feeble light and quickly burned out (52 F 300). Another claim to the lamp by Goebel was disproved in 54 F 678. Edison studied many different structures and made hundreds of tests before making the lamp shown in patent 233,898, issued January 27, 1880 (Fig. 13).

The main difficulty was finding a filament with enough resistance to operate satisfactorily from Edison's previously developed 110-volt dynamo. To be practical, the lamps had to be independent of each other, hence in parallel, and they had to use a high voltage and low current to keep down the size of the conductor. Edison knew that carbon had a high resistance and high melting point, and he believed that a thin, dense carbon filament would be best. He finally produced a carbonized thread 1/64 inch in diam-

*This is the last of four articles describing the 19 most famous American inventions, the background of the inventors, and how they profited from their developments.

1 "History of the Incandescent Lamp," J. W. Howell and H. Schroeder, Maqua Co., Schenectady.

T. A. EDISON.
Electric-Lamp.
No. 223,898. Patented Jan. 27, 1880.

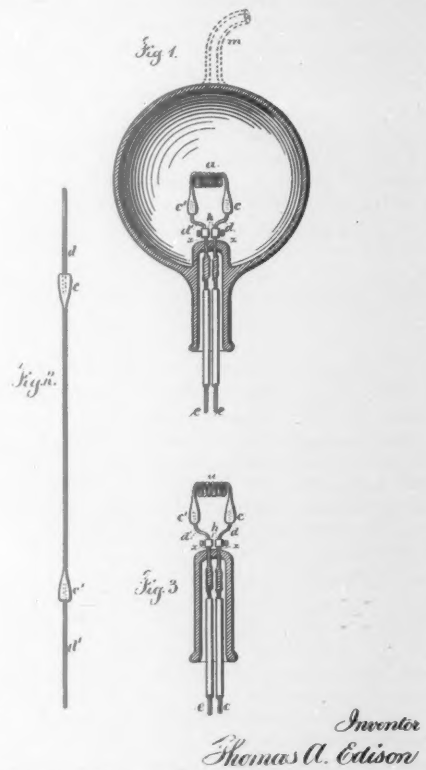


Fig. 13 — Edison's Incandescent Lamp.

N. TESLA.
ELECTRICAL TRANSMISSION OF POWER.
No. 382,280. Patented May 1, 1888.

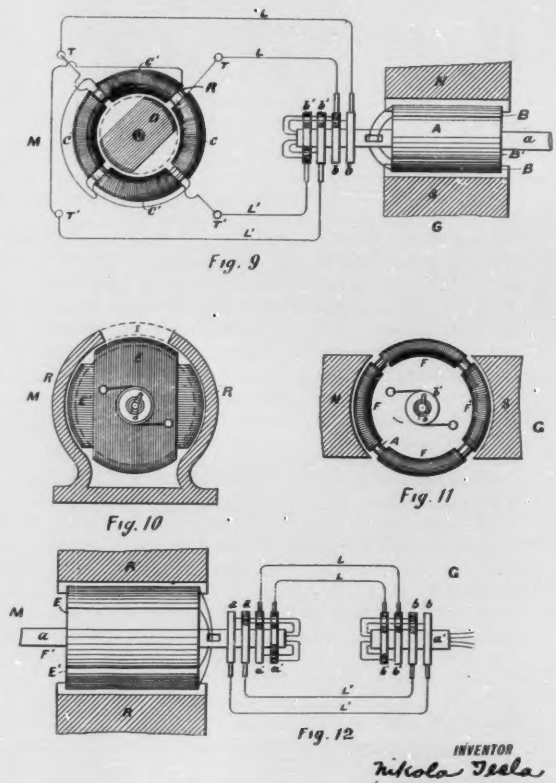


Fig. 14 — Tesla's Induction Motor.

T A. EDISON.
Phonograph or Speaking Machine.
No. 200,521. Patented Feb. 19, 1878.

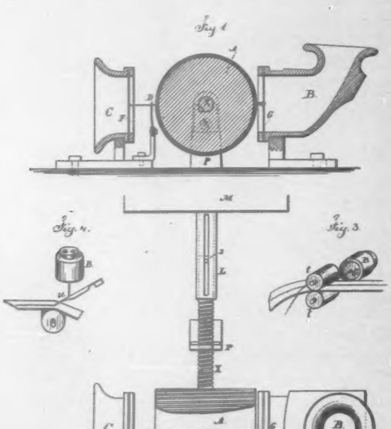


Fig. 15 — Edison's Phonograph.

T. A. EDISON.
APPARATUS FOR EXHIBITING PHOTOGRAPHS OF MOVING OBJECTS.
No. 493,426. Patented Mar. 14, 1893.

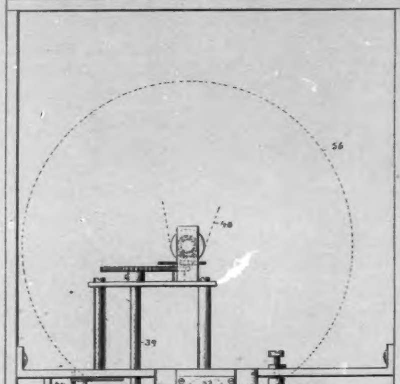


Fig. 16 — Edison's Motion Picture Projector.

C. M. HALL.
MANUFACTURE OF ALUMINIUM.
No. 400,665. Patented Apr. 2, 1889.

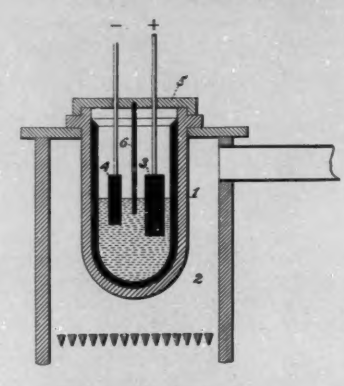


Fig. 17 — Hall's Aluminum Reduction Equipment.

eter, compared to the Sawyer and Mann rod of 1/32 inch diameter.

The results were remarkable, for the Edison lamp gave considerable light and burned for days before the filament broke. Edison had doubled the filament surface area and quadrupled the resistance. As a result, his lamp was eight times more efficient than the Sawyer and Mann lamp, and the electric lighting industry was born.

Edison followed up the filament invention by making the bulb a one-piece sealed container to maintain the vacuum, by improving the lead-in wires and by providing a screw base. Newspaper reports of these developments caused such a drop in gas shares that a near panic on the London Stock Exchange occurred on October 11, 1878. Professor Henry Morton, then president of Stevens Institute of Technology, protested against the publicity given the incandescent lamp demonstrations because "everyone acquainted with the subject will recognize it as a conspicuous failure."

Lamps were first made at Edison's Menlo Park laboratory, but their manufacture soon required a separate factory. Consequently, the Edison Electric Light Co. was organized in October, 1878, with a capital of $300,000, and a factory was built a half mile from the laboratory. The lamp factory was moved to Harrison, N. J., in 1882. Sockets and other fixtures were made in New York by a separate organization, Bergmann & Co., after 1880. Dynamos were built in the Edison Machine Works in New York beginning in 1881. All of these companies became a part of the General Electric Co. and were the forerunners of Edison illuminating companies throughout the country. In two years over 150 installations of "60-lamp" dynamos were made, and the first central station was built at Pearl Street, New York, in September, 1882.

Tesla's Induction Motor 1888

Nikola Tesla, the son of a Greek Catholic clergyman, was born (1857) at Smiljan Lika, Croatia (Austria-Hungary). It is said that Tesla's father intended him to be a clergyman but promised to allow him to study engineering only when his son was on his supposed death bed from cholera. Tesla was sent to Joanneum, a polytechnic school in Gratz, and to the University in Prague for two years. He started in the engineering department of the Austrian telegraph system, and then became an electrical engineer at an electric power company in Budapest and later in Strassbourg.

While in technical school, Tesla became convinced that commutators were unnecessary on motors; and while with the power company he built a crude motor which demonstrated the truth of his theory. In 1884, Tesla came to the United States and joined the Edison Machine Works as a dynamo designer. There he saw Edison's research laboratory, and he learned about Edison's methods and frequently violently disagreed with them.

Up to 1887, no practical small a-c motor was available (110 F 753), and factories were dark, dirty, and hazardous places with line shafting and belts to power individual machines. Power transmission was very inefficient, because 30 to 60 percent of the energy was wasted in turning the shafting, and power distribution was so inelastic that effective arrangement of the machinery was impossible. Ferrari, in a lecture published in Milan in April, 1888, is said to have described an induction motor; and French patent 190,946 to Borel discloses an electric meter also usable as an induction motor. A Westinghouse engineer, Shallenberger, independently invented polyphase and split-phase induction motors shortly after Tesla had completed his work on them.

In 1887 and 1888 Tesla had an experimental shop at 89 Liberty Street, New York, and there he invented the induction motor (patent 382,280, issued May 1, 1888), Fig. 14. This machine had a rotating magnetic field which eliminated the need for a commutator; it made unit drives for machines feasible and also made a-c power transmission an economic necessity. The experimental shop was moved to South Fifth Avenue, where all of Tesla's original models were later destroyed by fire.

Tesla tried unsuccessfully to sell his invention to the Mather Electric Co. early in 1888. However, with Brown and Peck, who had aided him financially, he sold the invention to Westinghouse in July, 1888. Tesla spent a year in Pittsburgh instructing Westinghouse engineers, including Shallenberger, who had been detailed to investigate induction motors and who recommended purchase of the Tesla patent. Westinghouse did considerable business in induction motors during the life of the Tesla motor patents and brought a number of infringement suits, and in each case the patents were held valid.

Tesla was given honorary degrees by Yale and Columbia Universities and by Vienna Polytechnic. He was awarded the Edison medal by the AIEE in 1917. The financial return to Tesla is unknown, but despite his 700 inventions he was not wealthy. Much of the time he did not even have a laboratory, and for many years he worked in his room at the Hotel New Yorker. He died January 7, 1943.

Edison's Phonograph 1878

Edison also invented two of the world's major amusement devices, the phonograph and the motion picture projector, either of which would be enough claim to fame for any average person.

Development of the phonograph was not the result of haphazard experimentation, but a direct result of the study of a practical problem. In 1876 the Western Union Telegraph Co. was losing business to the telephone, so it decided to investigate the telephone and employed Edison to do testing and development work on it. Edison soon developed both an improved receiver and the carbon transmitter. Work with the telephone impressed on Edison's mind the force avail-

able in sound waves, and he remembered how Bell had studied sound waves in developing the telephone.

Other work done by Edison for Western Union included the development of a telegraph message recorder and repeater on which dot-dash messages received were embossed on a paper disk on one turntable, and relayed from the disk to a transmitting key on another turntable. He noticed that a musical note was produced when a disk was turned at high speed, so he recorded the observation in his notebook. Edison also experimented with Bell's phono-autograph, which made a visible record of sound vibrations.

The combination of Bell's visible sound graph and telegraphic sound recordings as a result of his own experiments inspired Edison. He conceived the idea of recording sounds by making a continuous helical groove on a soft material with vibrations set up in a needle by sound. Running the needle, this time fastened to a diaphragm, through the groove again would cause vibration of the diaphragm and thus reproduce the sound.

As usual, getting an idea with Edison was immediately followed by steps to produce a machine embodying the idea.[2] Edison realized that he needed a lightweight surface large enough to move a recording point responsive to the air movements of sound. He tried a diaphragm and recording point on wax coated paper and got a fair response when he ran the paper back below the recording point. Edison had a model made similar to Fig. 14 so that he could use soft tinfoil, which was more permanent than wax paper.

The day and night of the first test was a scene of almost delirious enthusiasm as the men took turns trying the new machine, for they still couldn't believe that sound could be recorded and reproduced! The instrument shown in Fig. 15 (patent 200,521, issued February 19, 1878) is an almost exact duplicate of the first phonograph, which was the basis for the entire phonograph industry.

Edison demonstrated the phonograph to the editor of the Scientific American, and the press immediately spread the discovery over the world. Everyone wanted to see, hear, and own one of the new machines. The first phonograph was used only for public demonstrations, and Boston alone in one week paid $1,800 in admissions to the demonstrations. Edison manufactured and sold the hand-operated, tinfoil cylinder record photographs for the nine years during which he was developing the incandescent lamp. Edison then turned to making improvements in the phonograph, including the wax cylinder record and a mechanical drive which gave constant speed. It took eight months to produce a wax record satisfactory to Edison.

Edison organized the National Phonograph Co., which later became the Edison Phonograph Co., and he participated in the phonograph market for many years together with his licensees.

Edison's Motion Picture Projector 1893

The optical illusion, caused by persistence of vision of motion in pictures, was known before Edison's time. For example, toy books produced this illusion with slightly different drawings or photographs on each page, and strips of paper with a sequence of slightly different drawings or pictures mounted on a circular frame also created the effect of motion. In 1861, Coleman Sellers patented a toy for projecting images in step-by-step motion. Edward Muybridge, in 1880, projected pictures at the rate of 12 and 32 per second to illustrate his lectures on animal movements. Friese-Greene, early in 1880, "exposed a negative on a traveling film 3,000 times in five minutes."

LePrince in 1886 filed a patent application proposing perforation of a film with a sprocket running in the perforations for positive film movement. However, it took Edison to determine that the speed of operation should be 16 frames per second for optical continuity in the pictures. He then proceeded to develop a film drive and shutter mechanism with which such speed could be maintained, together with a heat shielded incandescent lamp and a lens system for projecting the pictures on a screen. The device was patented as No. 493,426 on March 14, 1893 (Fig. 16).

The motion picture projector was one example of an invention made before its time and without a serious attempt to introduce it to the public. As a result, it was not profitable to the inventor. The motion picture industry did not come into being until C. Francis Jenkins projected life-size pictures from films taken of a living, moving object (a vaudeville dancer) at Richmond, Ind., on June 6, 1894.

Hall's Reduction of Aluminum 1889

Modern life has just begun to make extensive use of aluminum, and it will certainly make greater use of light-weight metals in the future. The commercial reduction of aluminum was the result of the efforts of Charles M. Hall, who was born in Thompson, Ohio, in 1863, one of seven children of a Congregational minister. While a boy he read his father's chemistry book with interest, and he himself said, "I read about Deville's work in France and found the statement that every clay bank was a mine of aluminum and that the metal was as costly as silver. Soon after, I began to think of processes for making aluminum cheaply."

While a student in the general chemistry course at Oberlin College, Hall's chemistry teacher exhibited a few small buttons of aluminum which had been reduced from aluminum chloride by a known chemical method at a cost of eight dollars per pound (1878). The difficulties in the reduction of aluminum from its compound were outlined. A discussion of aluminum's properties again aroused Hall's interest and his appreciation of its possible uses. After graduation, he built a laboratory in the home woodshed and proceeded to study aluminum with the encouragement of his family

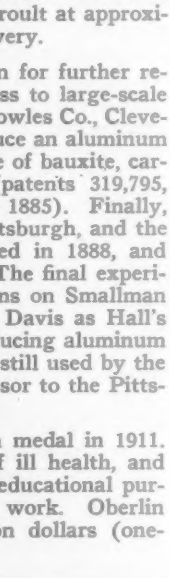
[2] 14 Journal of the Patent Office Society 39.

and of his former chemistry teacher, Frank F. Jewett.

Hall first experimented with various chemical reactions, and then he conceived the idea that if he could find a fused salt which would dissolve aluminum oxide, he might be able to electrolyze the solution to produce metallic aluminum. The first step was the discovery that molten cryolite would dissolve bauxite. Then Hall had to replace his clay crucible with one of carbon. On February 23, 1886, at the age of 22, Hall passed an electric current from ordinary storage batteries through a solution of alumina in molten cryolite in a carbon crucible, and produced a button of metallic aluminum. Hall's method is disclosed in his process patent 400,665, issued April 2, 1889 (Fig. 17), which shows the equipment used. The same invention was made independently in France by Heroult at approximately the same time as Hall's discovery.

Hall tried to find capital in Boston for further research needed for adapting the process to large-scale production. He tried to interest the Cowles Co., Cleveland, Ohio, which was trying to produce an aluminum alloy by electrically heating a mixture of bauxite, carbon, and copper to incandescense (patents 319,795, June 9, 1885; and 324,658, August 18, 1885). Finally, he found Capt. Alfred A. Hunt in Pittsburgh, and the Pittsburgh Reduction Co. was formed in 1888, and Hall became vice-president in 1890. The final experimental work was done in a few rooms on Smallman Street in Pittsburgh with Arthur V. Davis as Hall's assistant. No better process for producing aluminum is yet known, and the Hall process is still used by the Aluminum Co. of America, the successor to the Pittsburgh Reduction Co.

Hall was honored with the Perkin medal in 1911. He died in 1914 after many years of ill health, and his large fortune was distributed for educational purposes and for support of missionary work. Oberlin College alone received several million dollars (one-third of his entire fortune).



Baekeland's "Bakelite" 1909

Leo. H. Baekeland first carried condensation of organic chemical reagents to its commercial conclusion by producing a solid which could be plasticized by heat and molded as desired. Baekeland was born in Ghent, Belgium, in 1863 and graduated from the University of Ghent at the head of his class with a degree of doctor of science. He supported himself in college by tutoring fellow students. He taught chemistry and physics until 1889, when he visited the United States on a traveling scholarship.

In the United States, Baekeland accepted a position as a chemist with the Ansco Co. and continued a former amateur study of the chemistry of photography. In 1893, Baekeland and Leonard Jacobi formed the Nepera Chemical Co., where Baekeland developed "Velox" photographic paper as the culmination of ten years of work in photography. Velox is relatively insensitive to yellow rays of light and can be developed with relatively intense artificial light. Baekeland insisted that the manufacture of Velox be built into a going business before it was sold to the Eastman Kodak Co. As a result, he received enough money to make himself financially independent.

Baekeland now looked for a practical and interesting problem to occupy his time, so he chose to work with synthetic resins. In 1872 Baeyer had announced the principle that the reaction between phenols and aldehydes in the presence of an acid produced a resinous substance. The Hyatt brothers commercially introduced celluloid in 1874 (patent 156,353), thus creating a market for plastics. However, celluloid is limited in its use because it is inflammable and discolors. Manasse (United States patent 526,786), October 2, 1894, used formaldehyde, phenol, and a base to form a "phenol-alcohol." Stephen (United States patent 812,608, February 13, 1906) used the same materials from which "a red-brown liquid is produced out of which acids precipitate a deposit."

Baekeland did the initial work in his own laboratory with his own assistants and at his own expense for several years. He found that phenol and formaldehyde heated under pressure produced (patent 942,809, issued December 7, 1909) an amber transparent material which molded perfectly. Westinghouse engineers, under an arrangement with Baekeland, did development work on the use of "Bakelite" for laminated and impregnable products, and the Boonton Rubber Co. did development work on the molding of Bakelite.

Bakelite is the foundation for the Bakelite Corp. which was formed by amalgamation with the Condensite Co. of America and the Redmanol Co. It has since commercialized several synthetic plastics.

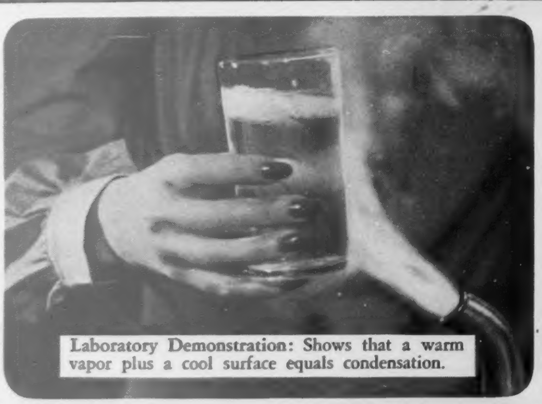
Baekeland, in addition to receiving ample financial returns, has been honored by the chemical profession. He received many medals and was given the highest honors possible to a United States citizen, by the Belgian government. His rewards were the result of thorough training, infinite patience, willingness to work, and a firm belief in the need for practical results. He died February 23, 1944, at Beacon, N. Y.

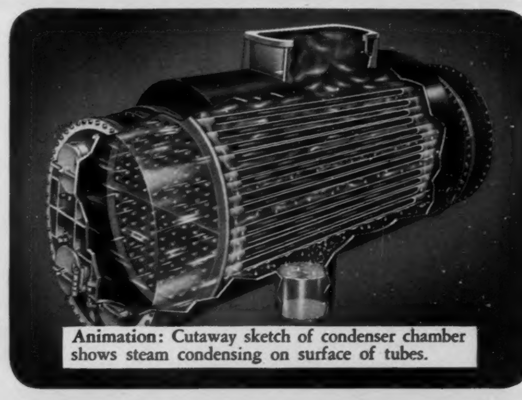
Consideration of the inventions of which America is proudest shows that the problems solved by the inventions had been subjected to numerous previously abandoned experiments and impractical solutions. Benefit to the public is the basis for all patents, but no such benefit was derived until the 18 men solved their several problems with intelligent observation and much hard work. The work required and the expenses incurred in showing practicality of the solutions of the problems alone are enough basis for any honor given to the inventors.

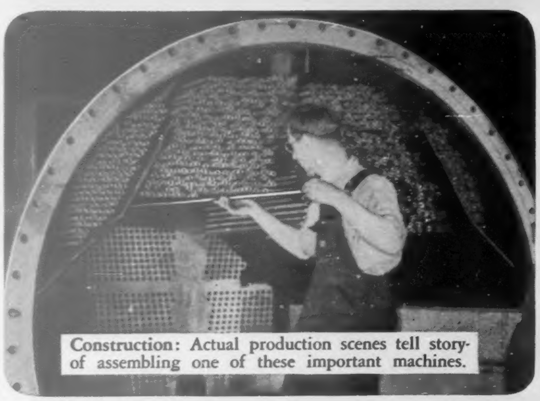
Each man had the additional ability and perseverance to continue work until a source of public supply of his invention was available, and only then did he receive any financial reward. The increased public convenience, health, and safety, and the number of people employed as a direct result of each invention, together with the subsidiary industries resulting, are more than sufficient basis for all the fame that can be given to the men responsible for such progress.

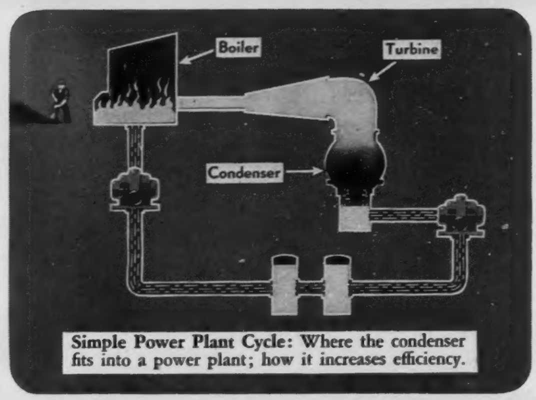
NEW MOVIE SHOWS WHAT HAPPENS

INSIDE A SURFACE CONDENSER


Laboratory Demonstration: Shows that a warm vapor plus a cool surface equals condensation.


Animation: Cutaway sketch of condenser chamber shows steam condensing on surface of tubes.


Construction: Actual production scenes tell story of assembling one of these important machines.



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